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LONGLEAF PINE



A magnificent stand of virgin longleaf pine. (Photograph courtesy of Long-Bell Lumber Company)

LONGLEAF PINE

Its Use, Ecology, Regeneration
Protection, Growth, and Management

By

W. G. WAHLENBERG, Forester
Southern Forest Experiment Station, Forest Service

*"The more extensive a man's knowledge of what has been done,
the greater will be his power of knowing what to do."*

DISRAELI.



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Published by the
Charles Lathrop Pack Forestry Foundation, Washington, D. C.
in cooperation with the
Forest Service, U. S. Department of Agriculture

79.35

V.11.2

C.2.

JAN 28 1946

FIRST EDITION

JANUARY 1946

79.35

V.11.2

755471

DEDICATED TO
A FUTURE IN AMERICAN FORESTRY
FOR
ONE OF THE FINEST TIMBER TREES
THE WORLD HAS EVER KNOWN

A Prefatory Note

The publication of a book on longleaf pine affords me very real and intimate satisfaction. This is not only because longleaf is one of our country's greatest timber trees—I have a more personal reason. For I belong to a generation that can still remember the vast virgin stands of longleaf that stretched coastwise from Texas to Virginia, and made the South one of the foremost lumber-producing regions of the world. I have ridden for many days through those open, sunlit forests.

That was thirty years ago. Today only scattered fragments remain, but there are abundant signs of a coming restoration of the forests of the South, and in that restoration one of the dominantly important trees is certain to be longleaf. In preparing for that time, if we are to avoid the heartbreak of wasted effort, lost years, and squandered dollars, we will need to avail ourselves of all existing knowledge on the silviculture and management of longleaf. We will need to know where and under what conditions it grows best, how it can be made to reproduce itself, how it should be harvested. In a word, we need to know everything that must be done to make it of greatest practical service to man.

It is precisely the purpose of this book to make that sort of information available. Here for the first time collected between the covers of one volume, are the gleanings of man's knowledge concerning longleaf, the fruits of research, the results of study and experience. Through the practical application of such knowledge lies our best hope for renewing and preserving one of the world's greatest timber trees.

RANDOLPH G. PACK, *President,*
Charles Lathrop Pack Forestry Foundation

Foreword

Longleaf Pine, by W. G. Wahlenberg, is a contribution of exceptional significance to the literature of American forestry. It is a comprehensive monograph, bringing together and interpreting such pertinent information as exists regarding one of the most important species of trees in the United States.

Since early settlement of the South, longleaf pine has been a notable factor in the development of the lumber and timber products industry, and it has been a major source of naval stores. Heavy drain by destructive practices of exploitation, uncontrolled fire, and, in many places, encroachment by competitive species of trees, have materially reduced the area of longleaf pine forests. The species still occupies a place of great importance, and will continue so, provided that measures such as set forth in this book are taken for its constructive management.

Progress in forestry is dependent on the advance of knowledge through research and the interpretation of results of trial and error. For a generation or more foresters, botanists and other scientists have studied the life characteristics, growth, and quality of products of longleaf pine. Forest literature is replete with articles and brochures setting forth the findings of these special studies. Mr. Wahlenberg, assisted by colleagues in the Forest Service and others, has assembled this scattered material, added unpublished data, and interpreted it for special needs of scientists and practitioners.

The author indicates that the primary purpose of the treatise is to aid the timber grower. Certainly it will serve as an invaluable guide to the landowner and timber operator, as well as the technical forester. The work clearly reveals the character, variability, and complexities of silviculture of longleaf pine. There are no uniform rules of practice that can be applied generally to secure reproduction and maintain a high standard of volume and quality growth, and thereby obtain maximum long-run financial values for timber growers. Discriminating judgment and skill are essential for this objective, based on information such as that provided in this monograph.

The book will be of great service to public forest officers in guiding policies and practice in handling public forest properties, in general public educational work and extension teaching. It will be welcomed by the forest schools for reference by faculty members and students. It provides specific illustrations of the character of technical problems involved in the management of a tree species of exceptional importance.

The monograph contains well selected information regarding the use and development of longleaf pine resources and the problems faced by landowners and the forest industries. The principles set forth should contribute directly to progressive stabilization of land ownership and use and thereby strengthen a sustained rural economy in many regions.

The publication should serve as a great stimulus to research regarding other species of trees and the forests of which they are a constituent element. It is hoped that this work will be followed by analogous comprehensive studies of other important species.

H. S. GRAVES

Author's Preface

This book deals with one of the most interesting problems in American forestry, and, with respect to the need for information, perhaps the most important one in the South. It is written in response to demands from many staunch believers in the economic worth of longleaf pine, once the most abundant of southern pines on the Atlantic and Gulf Coastal Plains, and now waning in commercial importance. Those who deal with longleaf are confused by conflicting or incomplete recommendations, varied treatments, and inconsistent results in regenerating the species. They seek, not more well-meant but puzzling advice, but fundamental information that will help them to solve their problems in their own way.

Information on forestry within the longleaf pine belt has been accumulating rapidly during the past 40 years. Of over 600 articles listed in this book, the great majority are recent contributions. The collection of data by various persons and agencies has been accelerated until it has finally outstripped the facilities for adequate individual interpretation. Literally hundreds of questions in longleaf pine management remain unanswered for lack of access to information already collected. Hence there is an obvious need for bringing together, in an orderly manner, data on longleaf pine in various files and libraries. Left scattered, much potentially useful knowledge would remain largely inaccessible to many foresters and timber growers, and the readily available information would be only partially effective in improving forestry practices. The present volume reviews both classes of this literature and adds unpublished information. It attempts to collect and synthesize as much useful and pertinent data as could be found.

The scope of the treatise is comprehensive. Certain immutable circumstances, however, have affected both the compilation and presentation of the material.

Some promising material was not in readily useful form, and some could not be used at all. For example, nearly all the statistics from the Federal Forest Survey of 1935 were originally compiled and reported showing longleaf and slash pines together as "turpentine pines." This made it impracticable to summarize the status of longleaf pine in the land occupied by the species, and in timber supplies, growth, and drain.

A second difficulty arose from the general absence of clear-cut policies and procedures among timber owners and foresters in handling the longleaf pine type. Because sound management can develop only with practice, our present dearth of experience necessarily leaves gaps in this book. For instance, field men need far more information on second-growth than on old-growth timber, which is almost entirely depleted. Yet published material on second growth is meager. New facts about second growth will, of course, accumulate steadily, and some will indicate the need for revision of accepted practices. Already we have had to revise some original concepts, such as the need for total exclusion of fire in longleaf forests. In fact, the vital role of fire in the life history of longleaf pine has not been realized until recent years. A more definite appraisal and report on longleaf will be in order perhaps two

or three decades hence, when the story can be revised in the light of greater practical experience in applied forest management.

In spite of the gaps in knowledge and the inaccessibility of some information, the present synthesis should be of value to many people—to practicing foresters, conservation agencies, progressive lumber, pulp, or turpentine companies, and landowners, engineers, and others who handle longleaf pine products. It should be of use to research workers, students and teachers of forestry, and, in the longleaf pine belt, forest managers handling the regeneration of this unusual species.

Together with information from timber cruises, growth studies, and market surveys, this book should supply the forest manager with otherwise inaccessible information, examples, and principles needed in analyzing local problems and in working out his own best methods for the culture and profitable utilization of longleaf pine. No attempt, of course, should be made to answer individual questions on the basis of this work without intimate acquaintance with conditions on local properties.

W. G. WAHLENBERG

New Orleans, La.
August 1945.

Acknowledgments

Helpful suggestions from many forestry colleagues who read parts of the rough draft of this book are gratefully acknowledged. The author is indebted to John R. Curry, I. F. Eldredge, C. A. Bickford, and P. C. Wakeley of the Southern Forest Experiment Station for staff assistance, and to Professors H. J. Lutz, R. C. Hawley, and H. H. Chapman of the Yale School of Forestry for encouragement.

Assistance in the preparation of the chapters on protection was obtained from local representatives of the Bureau of Entomology and Plant Quarantine in the section on insects, the Bureau of Plant Industry, Soils, and Agricultural Engineering on diseases, and the Fish and Wildlife Service on rodents and birds.

Constructive criticism of certain chapters was received from Kenneth P. Davis, former Chief of the Division of Forest Management, Forest Service, R. M. Nelson and other members of the Appalachian Forest Experiment Station, and from Francis H. Eyre, Paul O. Rudolf, and E. I. Roe of the Lake States Forest Experiment Station. The section on properties of wood was reviewed by R. A. Hertzler, Eloise Gerry, Benson H. Paul, E. Beglinger, G. M. Hunt, R. F. Luxford, C. V. Sweet, E. R. Schafer, and F. L. Browne of the Forest Products Laboratory, Madison, Wis. Special acknowledgment is due to Mrs. Cleo Thornton for improving the organization of the tables and charts, Miss Beryl G. Gardner for editorial assistance, Mrs. Roberta C. Watrous for checking the bibliography, Miss Theresa G. Hoerner for a statistical check of the manuscript, Miss W. L. Hughey for copying drawings used as Plates 4, 5, 6 and 7, J. E. Powell and his assistants for drafting many of the charts, and to W. P. Everard for preparation of the index.

The author is very much indebted to the American Tree Association for providing funds which made it possible for the Charles Lathrop Pack Forestry Foundation to publish this book.

Finally, special thanks are extended to the three men who helped with the book as a whole—to G. K. Stephenson and Henry Bull for a critical professional reading of the rough and final drafts, respectively, and to Anthony Netboy for assiduous editorial revision of the entire manuscript. Without their able help, many passages would have been more lengthy and less clear.



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INTRODUCTION

Introduction

THE LONGLEAF PINE PROBLEM

LONGLEAF PINE (*Pinus palustris* Mill.¹) once stood in extensive virgin forests of fabulous value; now it occurs mainly in smaller second-growth forests (Pl. 1).² Although there is no immediate danger that longleaf will vanish as a species, it is steadily waning as a natural resource. Where formerly it had complete possession of the land, it has often failed to reproduce; this failure has resulted in deterioration of land values in many localities. Furthermore, while longleaf is still widely distributed, there has been a tremendous shrinkage in the area exclusively occupied by the species—a recession that continues to this day.

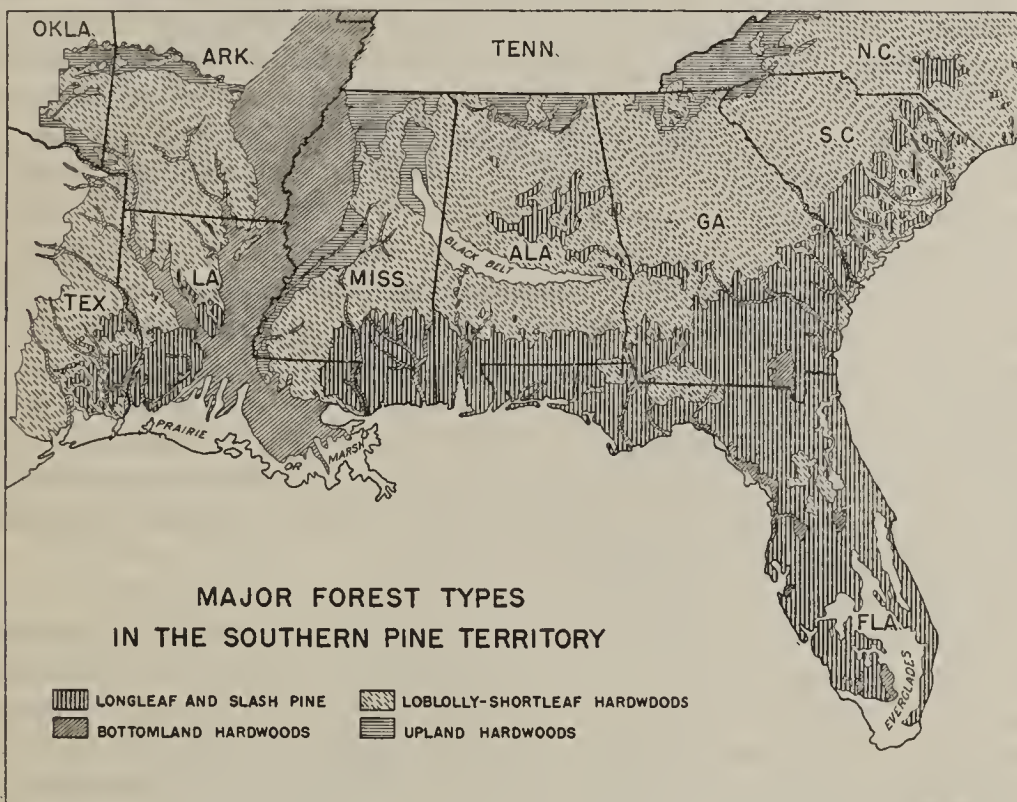


Figure 1.—Major forest types in the southern pine territory.

Many areas formerly dominated by longleaf pine have been taken over by other species. In the Southeast it has been largely slash pine (*P. caribaea* Morelet), and elsewhere loblolly pine (*P. taeda* L.), shortleaf pine (*P. echinata* Mill.), scrub oaks³ and other hardwoods. The principal forest types in the South are shown in Figure 1.

¹The various common names used to designate this species are given in Appendix I. The word longleaf in this book refers to *Pinus palustris* Mill.

²See pages 359 to 406 for Plate illustrations.

³Such as blackjack oak (*Quercus marilandica*), bluejack oak (*Q. cinerea*), turkey oak (*Q. laevis*), dwarf post oak (*Q. stellata* var. *margaretta*), and southern red oak (*Q. falcata*). This last is scrubby only in the longleaf type.

Two major factors account for the frequent failure of longleaf pine to perpetuate itself. First are the many conditions that handicap the seedlings, causing regeneration to be scanty or absent in numerous places. Among these may be listed too frequent fires, fires when the seedlings are in their first year, lack of fire where competition with other species is keen, and damage by hogs. Second, certain methods of removing the old growth have left little or nothing on the ground to insure further productivity. Rarely have enough seed-bearing trees of adequate size been left on cut-over lands.

Logging can be traced through three periods: (1) from the earliest settlements to about 1900, (2) from 1900 to about 1930, and (3) since 1930. Logging was confined in the first period to a narrow coastal region with small tidewater sawmills; in the second it centered around large inland mills; and in the third it spread, with the help of scattered small mills, over a network of highways reaching all parts of the longleaf forest. The main source of power for skidding logs changed from animals to steam to gasoline. Similarly, the principal vehicle for hauling logs was first the barge, then the railroad, and finally the auto truck. In 1880, water was almost the sole means of transporting longleaf pine logs, but by 1904 over 2,000 miles of logging railroads had been built in the longleaf region (142).⁴ These have largely been supplanted by highways and trucks.

The logging methods used in the first period caused only minor injuries to the forest, but increased mechanization, combined with more complete utilization, made the second period very destructive (Pl. 2). Because of smaller operations and some return to animal power in skidding logs, recent methods of logging have been less destructive to the remaining stand. Nowhere, however, has the exploitation of longleaf pine been geared to maintenance of the resource. It is consequently apparent now that present resources can be maintained or increased only as the result of careful planning for sustained-yield operations. This does not necessarily mean that all existing longleaf pine forests should be perpetuated.

Local forest conditions usually justify one of three practical policies:

First, where extensive destruction of virgin stands decreases the likelihood of either a second commercial cut or a new forest, the land can in many instances be advantageously devoted to nonforest uses. Once the decision is made to convert forest land to another use, management problems are greatly simplified. Naturally, the efficient liquidation of a short-term forest investment can be conducted more easily than the profitable management of a long-term enterprise. The first course circumvents any responsibility for future productivity of the land. Indeed, liquidation may simplify merchandising by disposing of all products to the highest bidder, thus dispensing with the skilled management necessary for properly integrated utilization of forest products.

Second, where only moderate protection and nonintensive improvements are needed to develop existing forests of fairly satisfactory species composition, simple forestry measures may be applied. Many extensive stands of fair to good second growth are close to good markets and often possess other local advantages that favor

⁴Italic numbers in parentheses refer to Bibliography, pages 324 to 358. This Bibliography lists a number of titles in addition to those cited in the text.

forestry. In general, the eastern part of the longleaf belt has a temporary advantage in growing stock, while the western portion has a permanent advantage in soils better adapted for heavy timber production. Some landowners will not attempt to grow another crop of longleaf where the native slash pine offers promising possibilities. There the advisability of incurring unusual costs to maintain the purity of the longleaf type is questionable. If no effort is made to favor any single species in regeneration, many intricate problems are circumvented, and forest management to produce either longleaf or some of its valuable associates is relatively simple.

Third, where full crops are sought and longleaf specifically is desired in new growth, more care is needed. To favor longleaf in reproduction, the mistakes made in handling most virgin timberlands must be avoided. Under some conditions natural reproduction is complicated and uncertain. This often means that local areas require fencing, planting, or the large-scale destruction of weed trees to obtain satisfactory longleaf regeneration. Land that is correctly managed for longleaf pine from the regeneration period onward should not require expensive corrective measures; well-established sapling stands need no expensive care.

Owners should decide whether or not they wish to maintain and reproduce longleaf in preference to other species. The information contained in this book will be helpful in making the decision.

ANATOMICAL CHARACTERISTICS AND SILVICAL PECULIARITIES OF LONGLEAF PINE

To identify longleaf pine and to recognize the advantages and disadvantages in growing and dealing with this tree in contrast to other southern pines, certain anatomical characteristics and silvical peculiarities must be considered. Typical bark, foliage, flowers, cones, seeds, and seedlings are illustrated in Plates 3 to 7, inclusive.

The leaves of longleaf pine have several distinguishing features (Pl. 4). The long needles—usually 8 to 12 inches long and sometimes reaching 18 inches—form characteristic dense tufts on older trees at the extremities of naked branches. The twigs, thick as a man's finger, are sturdier than those of other southern pines. On normally vigorous trees, longleaf needles are the longest of all pines, but on some individuals they are no longer than those of loblolly and slash pines. Borne three in a fascicle, longleaf needles are naturally three-sided, with each side bearing stomata. A remarkable weeping variety of longleaf with leaves 2 feet long is reported by Coker and Totten (120) from certain sections of North Carolina, especially around Rockingham.

Longleaf and slash pines differ from associated pines in the internal structure or cell pattern of the needles (238). These typically contain internal resin canals or ducts, i.e., resin canals that are not contiguous with the cells of the external or so-called dermal region, which consists of the epidermis or outer layer of cells, and the hypoderm or tissue just beneath the epidermis (Pl. 4, *F* and *G*). Sutherland (544) reported only internal resin ducts for longleaf pine. In slash pine she found that most but not all of the ducts were internal; occasionally median ducts occurred. Apparently the two species cannot be distinguished with certainty on this basis alone. The stomatic lines are less abundant in longleaf than in slash pine. According to Doi

and Morikawa (153), the two species may be distinguished by the hypoderm, which comprises only one or two cell layers in slash but three to six layers in longleaf. In longleaf the cells of the thin-walled layer are generally much smaller than those of the epidermis, whereas in slash they are often equal in size (125). In both species the diameter of the resin ducts varies, ranging from 0.04 to 0.05 mm. in longleaf and from 0.05 to 0.08 mm. in slash pine.

Juvenile characters are very distinctive. The seeds and cones of longleaf pine are the largest among the southern pines (Pls. 5 and 6). The cotyledons or seed leaves range from 6 to 10 per plant, the number varying even among seedlings from the same cone (594). The hypocotyl is so short that the seedling appears nearly stemless, a condition that persists throughout the "grass stage" (Pl. 7). Early in this stage, many seedlings have an abnormal terminal bud that produces needles but no shoot.⁵ This abnormal bud may occur rather late in the grass stage, but if it develops at all it always appears before the seedling enters the stage of active height growth. The first secondary foliage resembles grass, a condition which makes for low and unreliable reproduction estimates. In intensive studies the eye must be supplemented by touch and taste to identify the smaller stunted seedlings. Normally developed seedlings and trees have sturdy, erect, candlelike, needle-pointed buds. Bud scales are silvery-white, and fringed at the edges.⁶

In the early grass stage no regular annual rings are formed. As the stem thickens, indistinct and partial rings appear—the result of feeble, intermittent growth in spring and summer, and incomplete dormancy in fall and winter. Hence the rings formed in the early grass stage are not a record of the passing years (437, 438). The first distinct annual rings are formed in seedlings emerging from the grass.

Where growth is well maintained throughout the summer, there are wide bands of dark, dense summerwood. Longleaf wood, especially that from virgin timber, is heavy, hard, straight-grained, and has a strong resinous odor. Numerous resin ducts, scattered throughout the annual ring, are comparatively large and often visible to the naked eye.

Slash pine has often been preferred to longleaf in the production of naval stores because of its higher yields, faster growth (at least on the more moist sites), and lower rate of gum evaporation. Additional reasons for such a preference may be found in the difficulties of longleaf reproduction. Irregular and infrequent cone production is unfavorable to the natural regeneration of longleaf. The palatability of the large seeds to birds and animals frequently interferes with regeneration. Seeds for sowing in nurseries deteriorate rapidly unless kept in cold storage. The stemless

⁵Pessin (446, p. 225) says: "The fascicular meristem lies in a horizontal plane forming a flat surface out of which the fascicles arise. Then a slight convex curvature develops in the fascicle-bearing surface, and a semblance of a bud appears. Finally, a typical silvery-white pointed bud is formed, which develops into the main axis and from which the fascicles arise laterally."

⁶A natural hybrid of longleaf and loblolly pines, Sonderegger pine, was first reported by Chapman (97). Like longleaf, the hybrid seedling is said to be susceptible to needle disease and later capable of yielding naval stores. Like loblolly, the hybrid seedlings develop a stem 1 to 2 inches long in early spring of the first year, and later the leaf and wood structures resemble loblolly. After the first year, the seedlings are intermediate between those of their parent species in resistance to injury from hogs and fire, and in rate of growth. Stem elongation is 1 to 2 inches in the second season, 6 to 18 inches in the third season, and more rapid thereafter. Wakeley (591) found that the number of clean seeds of Sonderegger pine ranged from 12,730 to 14,138 per pound, averaging 13,400, which is midway between longleaf (5,200) and loblolly (21,300).

Table 1.—*Advantages and disadvantages of longleaf pine, in comparison with other southern pines, with respect to its production and use*¹

Characteristics	Natural reproduction	Artificial reproduction	Management for—					Conversion & processing			Used for—		
			Timber	Naval stores	Pulpwood	Wildlife (Quail)	Soil conservation	Workability	Handling	Shipping	Timbers and lumber	Pulpwood	Naval stores
Cones produced only at irregular and infrequent intervals	D	D											
Cones open slowly, may be abortive and hypertrophied, and may be diseased or infested with insects	D	D											
Seeds large and heavy, with persistent wings	D	D				A							
Seeds germinate promptly in fall or early winter ²	D	A											
Seeds difficult to keep in storage		D											
Seedlings in grass stage nearly stemless		D					D						
Seedlings and saplings produce thick bark early	A												
Seedlings delayed in emerging from the grass	D	D											
Low resistance to injury by hogs, sheep, goats, and brown-spot needle disease	D	D											
Intolerance of shade and inability to develop into trees under the canopy and among the roots of larger trees	D	D											
Outstanding resistance to fire, tip moth, rabbits, cattle, rust canker, poor soil, and dry facing under severe turpentine treatment	A	A	A	A	A	A	A						
Pronounced expression of dominance ³	A	D											
Facility in natural pruning			A	A	A						A	A	
Slow growth and long rotations			D				D	A					
Wood relatively dense and strong								D	D		A		
Contrast between springwood and summerwood								D					
Sapwood thin; resinous heartwood of relatively large volume											A		
Lower turpentine content and darker rosin grades (from gum of equal purity); gum contains more scrape and less dip than does gum from slash pine				D									D

¹A = Advantageous; D = Disadvantageous.

²Causes heavy winter loss of seedlings in coryledon stage from grass fires, but is advantageous in nurseries.

³Advantageous where seedling stands are dense and irregular; disadvantageous where spacing is relatively wide and under artificial control, as in plantations.

one-year seedlings are hard to ship and plant and to protect from silting after planting. Delayed growth, low resistance to injury by hogs and needle disease, and intolerance of competition result in high mortality of grass-stage longleaf seedlings.

On the other hand, there are many sound reasons for preferring longleaf pine. The outstanding advantages of this species in timber growing are its resistance to such destructive agencies as fire and certain insects and diseases (e.g., tip moth and rust canker), and its tolerance of poor soil and heavy working for turpentine. Early development of thick fire-resistant bark, relatively rapid natural pruning, beginning in the sapling stage, a pronounced expression of dominance, and adaptability to the production of large clear timbers are other important desirable characteristics.

The major distinctive characteristics of longleaf pine are summarized and evaluated in Table 1.

Part I

RESOURCES, USES AND PROPERTIES
OF LONGLEAF PINE

I. Longleaf Pine Resources

PURE longleaf pine forests now cover probably only from a third to a half of the territory once occupied. As will be indicated later, there is no accurate measure of this recession because the original area is unknown. As a guess, the pure longleaf forest probably once covered 30 to 60 million acres and now occupies only 15 to 20 million acres. Associated with other pines in mixed stands, of course, the species occupies a larger area.

Fernow (172) in 1892 estimated that the original longleaf pine forest contained 200 billion board feet of timber and that it would last 50 to 60 years at best. Such early estimates were made by measuring on large-scale maps the areas occupied by longleaf, and then deducting the areas in bottom lands, prairies, and clearings. Although in North Carolina more detailed surveys were available, in most cases timber volume was estimated by multiplying the forested acreages in each State by the average volume of timber per acre. According to a report on the lumber industry by the Commissioner of Corporations in 1911, the volume of longleaf and slash pine then standing in the South was 232 billion board feet (231).

Cutting of longleaf pine dates from the earliest settlement, but there are no records of the quantity of timber cleared from the land by farmers and early traders. By the time of the Revolutionary War the commercial value of longleaf pine was widely recognized, but only small areas had been fully exploited. No statistics are available to show how much was used in the next hundred years, but the annual cut probably approached half a billion board feet by the time of the Civil War, and perhaps 1½ billion by 1875. In 1880 the annual cut of longleaf pine was estimated at about 2 billion board feet (481) divided among eight States. Annual production increased steadily until the peak year of 1907 when more than 13 billion board feet were estimated to have been cut. The rate of decline in subsequent production is obscured by the common practice of grouping all southern yellow pines together in lumber statistics.

The exploitation of the original resources began on the Atlantic Coast and progressed from the Carolinas to Texas.¹ In general, the early operations left a fair number of small residual trees, often aggregating 1 or 2 thousand board feet per acre, sometimes 5,000 board feet. But loggers cut progressively more and more of the smaller trees until in Mississippi and Louisiana merchantable trees down to 8 or 10 inches in diameter at breast height were removed. Many residual trees were seriously injured by the steam skidding of logs, and after about 1915 logging usually stripped the land (185). In general, the earlier cuttings have restocked more satisfactorily than the later ones.

Timber resources in the South as a whole were surveyed in detail by the U. S. Forest Service in 1932-36. At that time the remaining stand of longleaf pine saw timber was estimated to be 19 to 22 billion board feet or about one-tenth of the

¹No account of the rapid depletion of the great longleaf pine forest would be complete without some reference to the men who directed the work and profited from it. Boyd (43) provides an interesting history of the industry in its early days.

original old-growth forest. Second growth had largely succeeded virgin timber throughout the longleaf pine region.

NAVAL STORES REGION

The term "naval stores region" as used here refers to the coastal region of the South from southern South Carolina to eastern Louisiana (Fig. 2) in which longleaf and slash, the turpentine pines, predominate. This is the naval stores or longleaf-slash pine region recognized by the Forest Survey. It contained nearly 12 billion

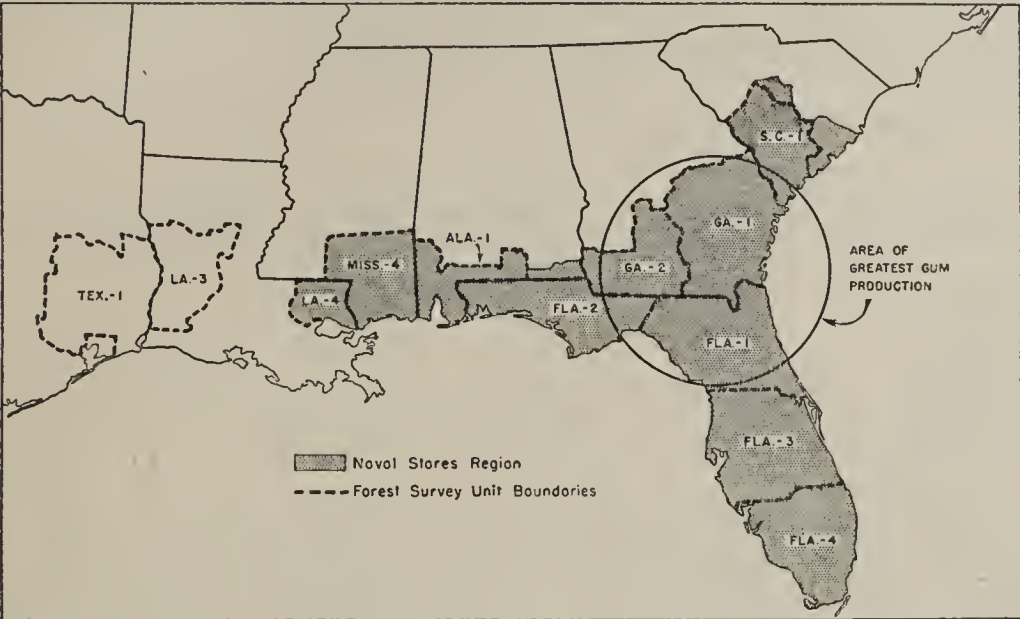


Figure 2.—Naval stores belt and longleaf region west of the Mississippi River, and forest survey units.

board feet of longleaf pine in 1935. Here the turpentine types of forest covered 29.4 million acres (Table 2) or 66 percent of the total forested area. Three-fifths of the turpentine pine types, or about 17.5 million acres, was in the pure longleaf type. About 9.9 million acres of the pure type were in rolling uplands, and 7.6 million

Table 2.—Distribution by States of the turpentine forest, and topography of the longleaf pine type in the naval stores region, 1935¹

Classification	Area	S.C.	Ga.	Fla.	Ala.	Miss.	La.	Total
	Acres	Percent						
Type of turpentine forest:								
Longleaf pine	17,527,600	59.6	3.9	17.8	55.1	8.6	11.9	2.7 100.0
Longleaf-slash pine	1,769,700	6.0	1.3	47.4	35.4	8.5	7.0	0.4 100.0
Slash pine	7,626,100	26.0	2.0	29.9	58.3	4.7	4.0	1.1 100.0
Slash pine-cypress	1,186,600	4.0	2.9	40.4	50.6	1.7	4.2	0.2 100.0
Turpentine pine-hardwood	1,279,800	4.4	5.3	35.1	23.4	13.7	19.7	2.8 100.0
All types	29,389,800	100.0	3.3	24.4	53.2	7.5	9.6	2.0 100.0
Topography of longleaf pine type:								
Flatwoods	7,559,400	43.1	2.3	18.5	75.9	1.3	1.2	0.8 100.0
Rolling uplands	9,902,300	56.5	5.1	17.2	39.5	14.1	20.0	4.1 100.0
Swamps, bays, ponds	65,900	0.4	2.4	44.8	25.6	13.1	14.1	0 100.0
All topography	17,527,600	100.0	3.9	17.8	55.1	8.6	11.9	2.7 100.0

¹From the Nation-wide Forest Survey conducted by the U. S. Forest Service. See Figure 2 for the location of the naval stores region.

acres in flatwoods. Approximately 55 percent of the pure longleaf type and about 53 percent of all turpentine pine area were in Florida. The remainder of the pure longleaf type was in Georgia (17.8 percent), Mississippi (11.9 percent), Alabama (8.6 percent), South Carolina (3.9 percent), and Louisiana (2.7 percent).

Table 3 shows stand conditions in the pure longleaf pine type in the naval stores region. About 9 percent of the longleaf area in the flatwoods was classed as old growth in 1935, and 45 percent was second growth, of which less than 30 percent was sawlog size. Nearly 3 million acres, or 37 percent, were clear cut, and only 642 thousand acres, about 8 percent, were covered with reproduction. The distribution of the pure longleaf type in the rolling uplands was similar, but here only 20 percent was clear cut, and 12 percent covered with reproduction.

Table 3.—Distribution by States of stand conditions in the pure longleaf pine type in the flatwoods and rolling uplands of the naval stores region, 1935¹

Classification	Area		South	Georgia	Florida	Alabama	Missis-	Louis-	Total
	Acres	Percent	Carolina	Percent	Percent	Percent	sippi	ana	
FLATWOODS									
Old growth:									
Uncut	166,300	2.2	0.5	9.4	89.1	1.0	0	0	100.0
Partly cut	529,200	7.0	2.0	32.2	63.7	1.1	0.4	0.6	100.0
Second growth:									
Sawlog size:									
Uncut	846,700	11.2	10.7	35.1	51.9	1.0	1.0	0.3	100.0
Partly cut	113,400	1.5	3.6	22.3	69.8	0	4.3	0	100.0
Under-sawlog size:									
Uncut	2,373,600	31.4	2.2	22.4	72.3	1.9	0.8	0.4	100.0
Partly cut	60,500	0.8	10.4	31.2	53.2	0	5.2	0	100.0
Reproduction	642,500	8.5	1.8	19.9	74.1	2.1	1.9	0.2	100.0
Clear cut	2,819,600	37.3	0	9.1	86.9	0.9	1.7	1.4	100.0
Fire killed	7,600	0.1	0	57.1	42.9	0	0	0	100.0
Total or average	7,559,400	100.0	2.3	19.2	75.2	1.3	1.3	0.7	100.0
ROLLING UPLANDS									
Old growth:									
Uncut	121,200	1.2	5.9	9.7	70.3	10.3	3.8	---	100.0
Partly cut	784,500	7.9	4.2	20.5	28.6	25.3	15.4	6.0	100.0
Second growth:									
Sawlog size:									
Uncut	1,369,600	13.8	11.6	24.2	37.5	15.4	9.9	1.4	100.0
Partly cut	175,300	1.8	7.5	23.5	30.0	15.1	22.9	1.0	100.0
Under-sawlog size:									
Uncut	4,155,600	42.0	6.2	19.7	41.4	13.6	16.6	2.5	100.0
Partly cut	147,000	1.5	8.6	17.6	24.2	30.8	14.7	4.1	100.0
Reproduction	1,173,200	11.8	2.1	13.8	29.4	10.4	34.8	9.5	100.0
Clear cut	1,974,200	20.0	(2)	7.3	47.4	11.1	28.2	6.0	100.0
Fire killed	1,700	(2)			47.1			52.9	100.0
Total or average	9,902,300	100.0	5.1	17.2	39.5	14.1	20.0	4.1	100.0

¹From the Nation-wide Forest Survey conducted by the U. S. Forest Service.
²Negligible.

Longleaf and slash pines in the naval stores region are generally turpentine as soon as they are large enough. In 1935 turpentine usually started when the trees reached 7 inches in diameter breast high. In 1944, largely as a result of the Naval Stores Conservation Program, turpentine generally started at 9 inches. In 1935 only 16 percent of the round turpentine pines in the naval stores region were 7 inches

and larger in diameter. Forty-four percent of all turpentine pines 7 inches and larger were being worked or were worked out; in southern Georgia alone, however, 63 percent were in this class, whereas in southern Mississippi there were only 21 percent. This illustrates the wide range of conditions within the naval stores region.

Saw-timber volumes of longleaf and slash pines in average second-growth stands of sawlog size in the turpentine pine types range from about 1,200 to about 2,300 board feet per acre (Table 4). The corresponding range in cordwood volumes is 5.2 to 10.5 cords (Table 5). Averages of this kind are useful mainly in comparing different forest conditions and survey units, and in picturing the general forest situation as it applies to large areas. Although data for second growth are of particular interest because that is the prevailing condition, the data for uncut old growth in Tables 4 and 5 give a much better picture of average productive capacity. Volumes in this condition show a much wider range than those for second growth; the high

Table 4.—*Net board-foot volume of longleaf and slash pines on the average acre in the turpentine pine types, naval stores region, by forest conditions and survey units, 1935¹*

Forest condition	State and survey unit								Miss. and La.
	S. C.	Ga.	Fla.				Ala.		
	1	1	2	1	2	3	4	1	4 & 4
Old growth:	<i>Board feet (Int. ¼-in. Rule)²</i>								
Uncut	5,478	4,291	6,716	5,567	3,791	3,659	2,192	8,395	13,878
Partly cut	3,825	2,655	2,649	2,203	2,215	1,846	1,504	3,161	2,684
Second growth:									
Sawlog size:									
Uncut	2,278	1,957	2,205	1,847	1,859	2,129	1,736	2,110	1,841
Partly cut	1,660	1,498	1,729	1,775	1,302	1,426	1,244	1,642	1,449
Under-sawlog size ³	238	268	325	241	195	212	175	208	182
All conditions ⁴	1,284	1,058	1,196	969	648	472	599	1,149	662

¹From Southern Forest Survey Release No. 29 (316). For location of survey units, see Figure 2.

²In usable logs in round pines 9 inches d.b.h. and larger and in turpentine pines at least 9 inches in diameter 10 feet above the ground. Includes turpentine butts, but no woods or mill cull.

³Does not include areas of reproduction or clear-cut forest conditions.

⁴Includes areas of reproduction and clear-cut forest conditions.

Table 5.—*Net cordwood volume of longleaf and slash pines on the average acre in the turpentine pine types, naval stores region, by forest conditions and survey units, 1935¹*

Forest condition	State and survey unit								
	S. C.	Ga.	Fla.	Ala.	Miss.				
	1	1	2	1	2	3	4	1	and La. 4 & 4
	<i>Cords</i> ²								
Old growth:									
Uncut	13.6	13.3	17.6	14.7	10.3	9.2	6.2	21.5	31.2
Partly cut	9.4	9.0	8.2	6.8	6.6	5.1	4.5	8.6	6.8
Second growth:									
Sawlog size:									
Uncut	10.5	10.0	10.1	9.4	8.4	8.5	7.1	9.4	7.0
Partly cut	7.4	7.6	8.1	8.3	6.0	5.5	5.2	6.5	6.3
Under-sawlog size ³ ..	2.3	3.0	3.2	3.0	2.1	2.0	2.1	2.3	1.4
All conditions ⁴	5.8	5.5	5.6	4.8	3.0	1.9	2.3	4.5	2.3

¹From Southern Forest Survey Release No. 29 (316). For location of survey units, see Figure 2.

²Outside bark, and including all sound material in merchantable trees 5 inches d.b.h. and larger. Top diameter 4 inches or larger.

³Does not include areas of reproduction or clear-cut forest conditions.

⁴Includes areas of reproduction and clear-cut forest conditions.

volume for old growth in southeastern Mississippi and eastern Louisiana, and the low volume for old growth in all of Florida except the northeastern part, are especially noteworthy.

Since it is highly desirable to obtain adequate natural reproduction following the cutting of mature trees, it is pertinent to examine the character of longleaf pine reproduction. Of the 1.8 million acres of reproduction in the pure longleaf type in the naval stores region in 1935, 14 percent was good (more than 900 well-spaced seedlings per acre), 32 percent was fair (170 to 900 well-spaced or 300 to 900 poorly spaced seedlings per acre), and 54 percent was poor (more than 80 but less than 170 well-spaced or 300 poorly spaced seedlings per acre). The proportion of good reproduction was lowest in central Florida (3 percent) and highest in northeastern Florida (22 percent). The proportion of poor reproduction was lowest in South Carolina and southern Mississippi (45 percent) and highest in southern Georgia (67 percent).

Conditions favorable to forestry are found in the northeastern part of Florida, but not in the northwestern, central, and southern parts. In northwestern Florida poor sites and heavy cutting resulted in an average annual increment of only 36 board feet per acre in 1935 (526). In the deep, coarse sands of western Florida growth of pine timber is too slow for forestry to be commercially feasible. In southern Florida longleaf and slash pine stands are typically light, mainly because of poor soil. Stands of less than 2,000 board feet per acre make up 60 percent of the sawtimber area and 36 percent of the volume.

In Georgia and northeastern Florida most of the turpentine pine area is attractive from a forestry standpoint. This is the center of the naval stores industry, and markets for other forest products are also good. The soils are for the most part distinctly unsuited to agriculture, but support good stands and timber growth. Slash pine is abundant and generally comes in where longleaf fails.

In South Carolina longleaf is largely confined to the poorer sites, having given way to slash and loblolly on most of the better sites. Forestry opportunities are generally as good as in Georgia and northeastern Florida.

In southern Alabama, southern Mississippi, and in Louisiana east of the Mississippi River, there are extensive pure stands of longleaf second growth of turpentine size. Many of these stands are well stocked and on good soils (170, 527).

WEST OF THE MISSISSIPPI RIVER

As shown in Table 6, there are 2.9 million acres of the pure longleaf pine type in southwestern Louisiana and southeastern Texas. There is no native slash pine in this region, hence longleaf is the only turpentine pine. Since this region is the scene of the most recent and heaviest cuttings in longleaf pine, it is not surprising that there is a larger proportion of clear-cut areas here than in the naval stores region. Eighty-four percent of the clear-cut longleaf land, or about 1.1 million acres, is in southwestern Louisiana, and accounts for 54 percent of the entire longleaf pine type in that survey unit. The majority of the sawmills that created this condition were established between 1900 and 1915. Cutting and logging damage was so heavy that only 15 percent of the clear-cut area contained even as many as 3 seed trees per acre

Table 6.—Area in pure longleaf pine type of forest by forest conditions, west of the Mississippi River, 1935¹

Forest condition	Southeastern Texas		Southwestern Louisiana		Total west of Mississippi River	
	Acres	Percent	Acres	Percent	Acres	Percent
Old growth:						
Uncut	25,900	2.8	58,500	3.0	84,400	2.9
Partly cut	102,400	11.0	64,700	3.3	167,100	5.8
Second growth:						
Sawlog size:						
Uncut	175,400	18.8	187,100	9.5	362,500	12.5
Partly cut	39,800	4.3	59,300	3.0	99,100	3.4
Under-sawlog size	298,300	32.0	383,500	19.6	681,800	23.6
Reproduction	94,000	10.1	153,500	7.8	247,500	8.6
Clear cut	195,600	21.0	1,055,600	53.8	1,251,200	43.2
Total	931,400	100.0	1,962,200	100.0	2,893,600	100.0

¹From Forest Survey Release No. 26 (131).

in 1935. In southeastern Texas, 27 percent of the clear-cut area contained at least 3 seed trees per acre. Practically all of this class of land will have to be planted if it is to be restored to forest productivity.

In 1935, 43 percent of the acreage in the pure longleaf pine type of forest west of the Mississippi was clear cut. Twenty-four percent was second growth under sawlog size, thus emphasizing the fact that heavy cuttings have been relatively recent. Second-growth longleaf of all sizes was proportionately more abundant in Texas than in Louisiana. Longleaf reproduction occupied only 9 percent of the total longleaf area, and was matched in this respect by old growth. In both States longleaf second growth is very irregular in density.

The total volume of longleaf pine west of the Mississippi was 2.8 billion board feet in 1935, or about one-fourth of the corresponding volume in the naval stores region. The volume on the average acre of longleaf second growth west of the Mississippi was about 1,800 board feet for uncut sawlog-size stands and about 1,400 board feet for partly cut sawlog-size stands. These are very similar to the averages for the naval stores region. Uncut old-growth longleaf, however, averaged 14,000 board feet west of the Mississippi River. This is slightly better than the southern Mississippi and northeastern Louisiana old growth, which was by far the best in the naval stores region. This condition is evidently due mainly to the much heavier soils in the western part of the longleaf region. With such favorable sites, it is doubly unfortunate that so much of the area has been stripped and left unproductive. Forestry opportunities are excellent in the relatively small part of the area where the stocking is good.

OTHER AREAS

Outside and to the north of the two principal longleaf regions described in the preceding paragraphs, there was in 1935 an appreciable area of the pure longleaf type distributed, by States, as follows: Mississippi, 118,300 acres; Alabama, 989,800 acres; Georgia, 330,000 acres; South Carolina, 732,600² acres; and North Carolina, 813,500² acres. In addition to this pure longleaf type, there was also a considerable

²Includes longleaf in mixture with other pines, longleaf predominating.

area of types containing longleaf mixed with other pines and hardwoods. These were distributed as follows: Mississippi, 95,800 acres; Alabama, 607,700 acres; Georgia, 161,700 acres; South Carolina, 70,600³ acres; and North Carolina, 49,600³ acres.

Although the totals are large, these types consist mostly of relatively small and irregular stands of longleaf and associated species scattered through a region which is dominated by the shortleaf-loblolly-hardwoods type. Forest conditions in these longleaf types are generally similar to those in the naval stores region, but vary widely from one State or part of a State to another. On the whole, there is a smaller proportion of clear-cut areas than in the naval stores region. Site conditions also vary widely, from flatwoods to hilly country. The total volume of longleaf pine in these scattered stands in 1935 was about 6 billion board feet.

SUMMARY

The virgin forest of about 200 billion board feet of longleaf pine was cut at an annual rate that increased steadily from about 1 percent in 1880 to about 6 percent in the peak year of 1907. Heavy exploitation of the original resource began on the Atlantic seaboard and progressed from the Carolinas to Texas. Second-growth forests are more abundant in the eastern than in the western part of the longleaf pine region. Occupying perhaps a third to a half of their virgin domain, and containing only about one-tenth of the original saw-timber volume, the new forests are nevertheless of great commercial value.

In many of the second-growth forests, which came in naturally on cut-over lands, longleaf pine has been partly or wholly replaced by other species, notably by slash pine in the Southeast, and elsewhere by loblolly and shortleaf pines or hardwoods. By 1935 the 29 million acres of turpentine forest remaining in the Southeast was only about three-fifths pure longleaf. While the heavier soils at the western end of the longleaf belt are potentially superior sites for longleaf, there is a larger proportion of clear-cut areas than in the naval stores region. The average partly cut second-growth stand contains about 1,400 board feet per acre. In the naval stores region, however, expanding markets for naval stores, sawlogs, poles and piles, and pulpwood, have created a favorable situation for forestry wherever there is adequate regeneration.

³Includes longleaf mixed only with hardwoods, not with other pines.

II. Uses and Properties

IDENTIFICATION OF LONGLEAF WOOD

FEW of the characteristics of longleaf pine wood are sufficiently distinctive to differentiate the species. Only one, the large size of the pith and the outside diameter of the second annual ring surrounding it, has been useful in identification, and then only in a limited way. As shown in Figure 3, this permits of positive

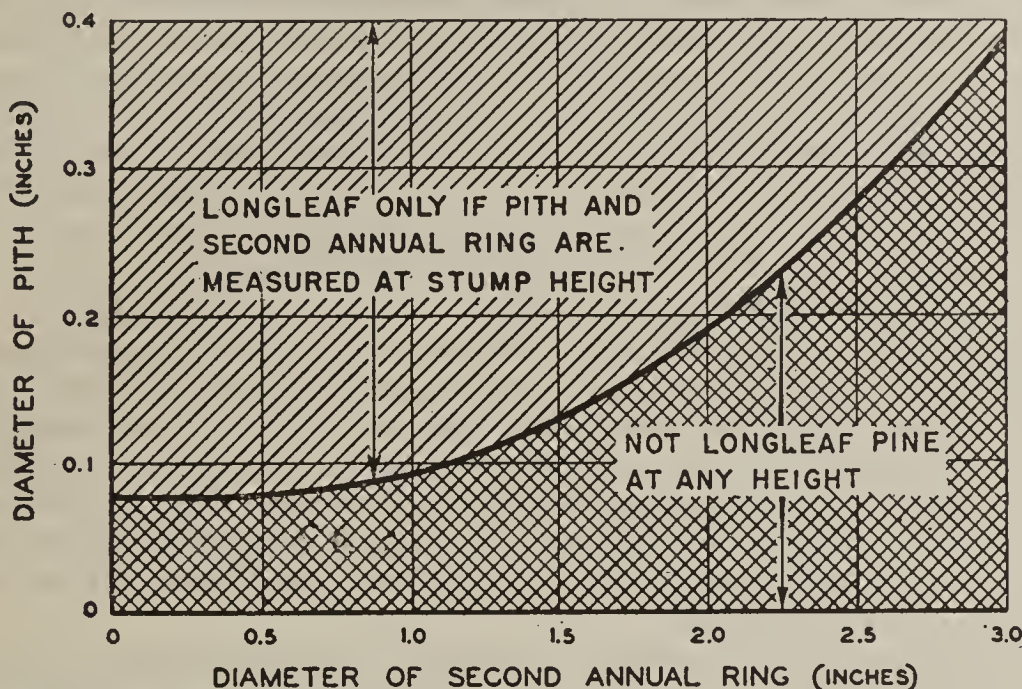


Figure 3.—Koehler's method (328) of distinguishing longleaf from shortleaf, loblolly, and slash pine wood. If the pith is less than 0.08 inch in diameter, the timber is *not* longleaf pine. If it is over 0.08 inch, the diameter of the second annual ring around the pith should be measured. With these two figures locate a point on the chart. Points below the curve indicate that the specimen is not longleaf; those above the curve indicate longleaf, providing the wood or log was cut at stump height. If the point is above the curve but the location of the cut is uncertain, apply this method to the opposite end, which may give a point below the curve and show that the timber is not longleaf.

identification from cross sections at stump height only. If the stump end is not identifiable¹ or available for examination, longleaf wood can be identified on the basis of the diameter of the second annual ring and that of the pith, but with somewhat greater chance of error.

PRINCIPAL COMMERCIAL USES

Lumber and pulpwood from the harvested tree, and naval stores from living trees, are the principal products of longleaf pine.

¹Such cuts can usually be recognized by butt swell, a relatively high percentage of summerwood, irregularly shaped heartwood, noncircular annual rings, turpentine scars, and absence of large knots.

Excellent service in various types of structures accounts for much of the lasting popularity of longleaf pine. Beginning about the middle of the 18th century, longleaf lumber was used for a great variety of purposes. Seventy-five to 80 percent of the village houses in the Carolinas, Georgia, and Florida in the 19th century were built of longleaf, except for the roofs, and on farmhouses even the roofs were of longleaf pine. Little lumber was shipped to the North until the supply of white pine waned. Longleaf was used for spars and masts, large quantities being exported to England for this purpose. Indeed, except for unusually large members, naval architects preferred longleaf to all other pines (476). Michaux, in 1810, pointed out that trees 15 inches or larger in diameter were merchantable but acceptable for export only if they could produce all-heart timbers at least 10 inches square. Timbers 14 inches square, free of sapwood, and 45 to 60 feet long, were popular in the export market (231). Even before the Revolution longleaf was exported to Cuba, and so-called ranging timbers—planks 10 or 12 inches wide and 15 to 30 feet long—sold in England at prices 25 or 30 percent above those of other American pines (72). In 1888 Mohr stated that shipments of longleaf products, including lumber, deals, square timber, and naval stores, to foreign ports and distant domestic markets were valued at 20 million dollars annually (396).

Except for an early prejudice against the use of timber from turpentine trees, longleaf was widely prized as lumber. It was unsurpassed for dimension stock, posts, piles, and joists, especially in bridge, trestle, warehouse, and factory construction. Its strength and stiffness made it suitable for railroad cars, railroad ties, farm implements, paving blocks, flooring and miscellaneous products (231). Longleaf was supreme in ship and wharf construction, except for the largest masts, where white pine was superior. Wharves in nearly every port from New Orleans to New York are largely built with longleaf.²

The reputation of longleaf pine originated with old-growth structural timber. In later years the other southern pines—slash, loblolly, and shortleaf—helped to maintain longleaf in its favored position, since many of their best specimens (densest wood) were sold as longleaf. Besides holding an export market for structural timbers, longleaf continues to be used for many of the purposes also served by the other southern pines, such as poles, piles, mine timbers, blocks, veneer and fuel.

One of the outstanding features in the utilization of virgin longleaf pine was the transition from prodigal waste to fuller use of the tree. Bray (47) pointed out that in Texas from 1875 to 1890, when it did not pay to cut clean, a good deal of timber was left on the land, but in the heavier cuts that followed, large numbers of saplings and poles were destroyed—sometimes amounting to two or three times the number of stems brought to the sawmill. In those days farmers had no scruples about chopping into the finest trees to test the grain for shingles and boards, and then permitting fires to aggravate the injury. Only about 44 percent of the tree volume

²The Longleaf Yellow Pine Manufacturers Association recommends longleaf for (1) *residential construction*: sills, joists, framework, sheathing, and floors; (2) *railroads (especially for bridges)*: caps, stringers, sway braces, ties, and guard rails; (3) *highway bridges*: same items with the addition of decking; (4) *freight cars*: decking, framing, siding, and roofing; (5) *factory construction*: columns, beams, flooring, and roofing plank; (6) *waterfront construction*: wharves, breakwaters, sheet piling; (7) *oil fields*: derricks and other temporary structures (117).

was used. About three-fourths of the volume of the harvested tree was converted into sawlogs and only about half of the log volume was made into salable products.³

This situation did not improve much while steam skidders were widely employed. In some mills, however, new uses were found for refuse. For example, a mill that once was able to use only 37 percent of the total volume of its merchantable sawlogs reported the following virtual elimination of waste: a \$75,000 burner that consumed an estimated 2,688,000 cords of sawmill refuse in 16 years became obsolete in 1924, after which much of this material was used in the manufacture of kraft paper (193, 121). Many companies, however, are still making poor use of what was formerly wasted—as for example burning refuse under boilers. Mill waste—including fuel—is currently estimated at about 1½ tons of dry wood per thousand feet of lumber cut. Lumber companies have a long way to go before they attain a high degree of utilization of the forest resource, but there is a great potential future in the chemical conversion of wood into alcohol, plastics, livestock feed, and other commercial products.

Lumber Production and Values

Stumpage prices of longleaf pine increased a hundredfold, from about 10 cents to over \$10 per M board feet, between 1883 and 1923. The average for all southern yellow pine jumped from 80 cents per M board feet for stumpage, \$5 for logs, and \$9 for lumber in 1900 to \$6, \$11 and \$30, respectively, in 1923. In the next decade these levels dropped about one-third, but advanced again in the 1930's and early 1940's. The long-time trend of all yellow pine prices has been distinctly upward.

Production of southern yellow pine lumber reached a peak of 16 billion board feet in 1909, much of which was longleaf, and fell to 3 billion board feet in 1932.

³In 1920 the Committee on Wood Utilization and Prevention of Waste of the National Lumber Manufacturers Association estimated the waste (cubic volume) in the utilization of longleaf trees as follows:

	Utilized Percent	Culled Percent
Tops (portion above sawlogs):		
Needles and twigs	----	2.2
Limbs under 2 inches	----	2.5
Red and rotten wood	----	6.6
Cordwood	6.4	----
Pulpwood	4.5	----
Total	10.9	11.3
Merchantable bole (between stump and top):		
Red and rotten wood	----	1.5
Slabs, edgings, and trimmings	----	18.1
Sawdust and shavings	----	17.6
Shingles1	----
Laths	1.4	----
Lumber and box shooks	32.0	----
Total	33.5	37.2
Lightwood	----	.6
Stump	----	6.5
Total	33.5	37.2
Whole tree (i.e., aerial portion)	44.4	55.6

Production increased enormously in response to the demands of World War II. Longleaf now constitutes perhaps about a third of the southern yellow pine output.⁴

The market values of longleaf sawlogs and stumpage have been consistently higher on the average than for shortleaf and loblolly pines. The demand for the waning supplies of virgin longleaf pine boosted stumpage prices materially between 1920 and 1925, and the subsequent exhaustion of old-growth timber brought the average prices of all pine timber closer to that for second growth. In short, the supply of virgin timber gave out while the demand was still active.

The superior value of large trees is due partly to their suitability for large timbers, partly to the lower cost per unit volume for logging and milling, and partly to a higher unit price for their lumber. The increase in board-foot content of the higher-grade products with tree size is shown in Figure 4, and the percentage of lumber by grades from logs and trees of different diameters in Figure 5. On the average, the proportion of the better grades does not increase as fast with tree diameters as it does with log diameters because of the presence of small knotty top logs. Were these top logs used for pulp rather than lumber, the graph for trees in Figure 5 would more closely resemble that for logs. Small trees not only yield lower-quality lumber than do large trees, but are more costly to handle (195).⁵ Small portable sawmills with low overhead can profitably use small logs, sometimes down to 8 inches, but the larger mills usually lose money on logs less than 12 inches in diameter. The greatest profit is in logs over 24 inches. Small thrifty trees, however, are valuable as growing stock, whereas logs from the tops of large trees may be profitably pulped.

Naval Stores

Longleaf pine has been used for naval stores production since the landing of the earliest colonists in Virginia. Tar and pitch for calking wooden ships were exported from Virginia as early as 1608. A hundred years later the value of these products shipped annually to England amounted to \$265,000 (390). At that time rosin was thrown away. In North Carolina turpentine started in 1665, but the production of rosin did not begin until about 1750 and did not become important until about 1890 (368), when the value of naval stores was estimated at \$8,000,000 annually (172). The products of the naval stores industry are used in the manufacture of paint, varnish, linoleum, paper, soap, ink, grease, synthetic camphor, and many other articles (557).

Naval stores products, even on the poorest lands, generally yielded more profit than did agricultural products from the richest lands in the same region (476). By 1895 naval stores output had an annual value of nearly \$10,000,000; some 2.5 million acres of forest were being turpentine and nearly 1 million additional acres were invaded each year. The annual market value rose to a \$71,000,000 peak in 1920 and dropped to about \$14,000,000 in 1940.

⁴Botanical species of pine are not separated in statistics of the lumber trade covering southern yellow pines.

⁵Garver, R. D. Longleaf pine: costs and returns for logs and trees of different sizes. 1931. U. S. Forest Service, Forest Products Laboratory. [Unpublished.]

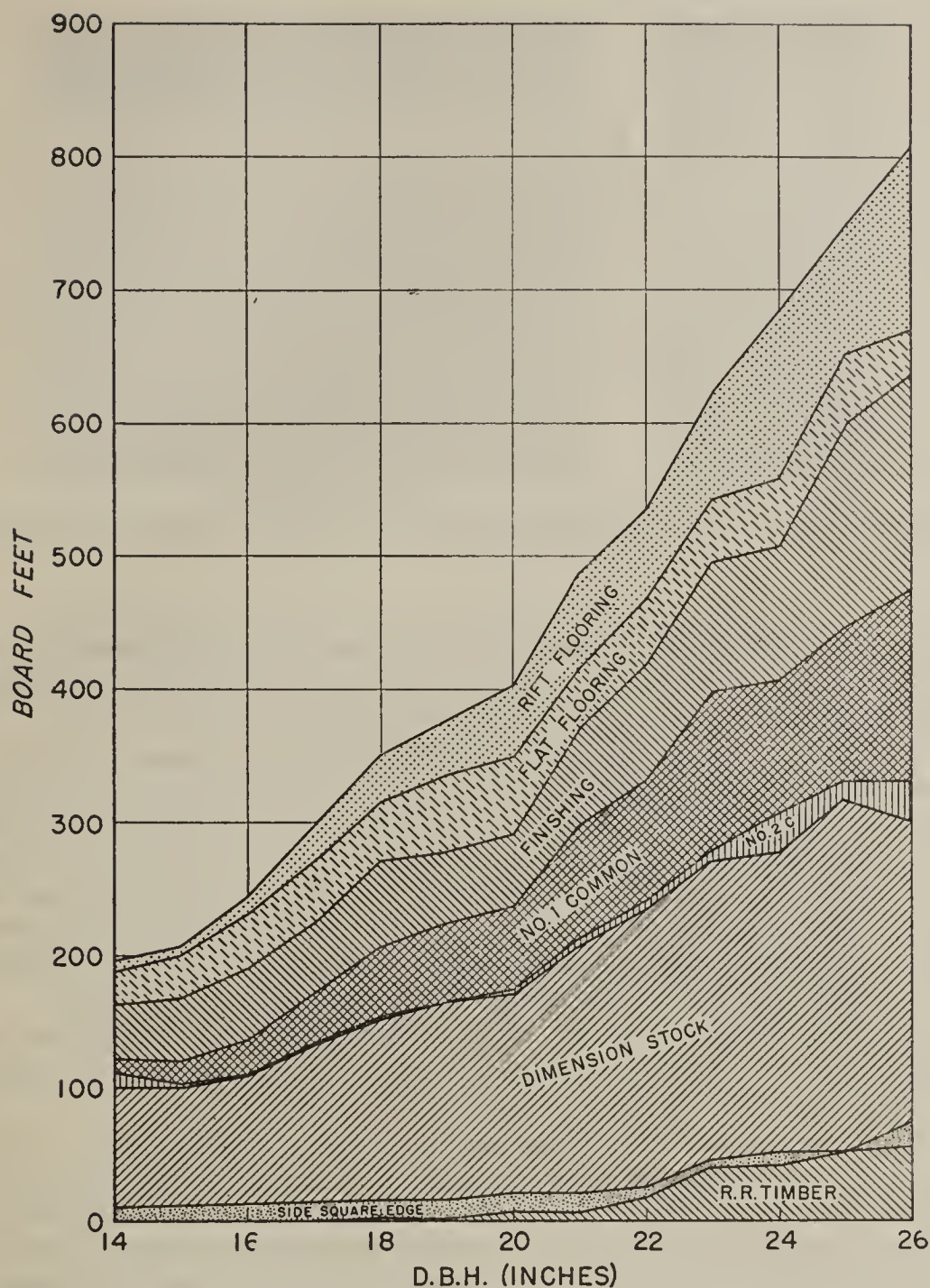


Figure 4.—Average quantities of lumber products sawn from virgin longleaf pine trees in a 6-week period at a central Alabama mill, 1905. (After Reed)

The position of gum naval stores in the industrial world is weaker today than it was 25 years ago, owing to changes in supply and demand. The peak in production, reached in 1908, roughly corresponds to the exhaustion of most virgin-timber supplies. At that time, much of the second growth was still too small to work. By 1940 the second-growth supplies were abundant, but meanwhile demand was reduced by increased production of naval stores from distillation of wood, com-

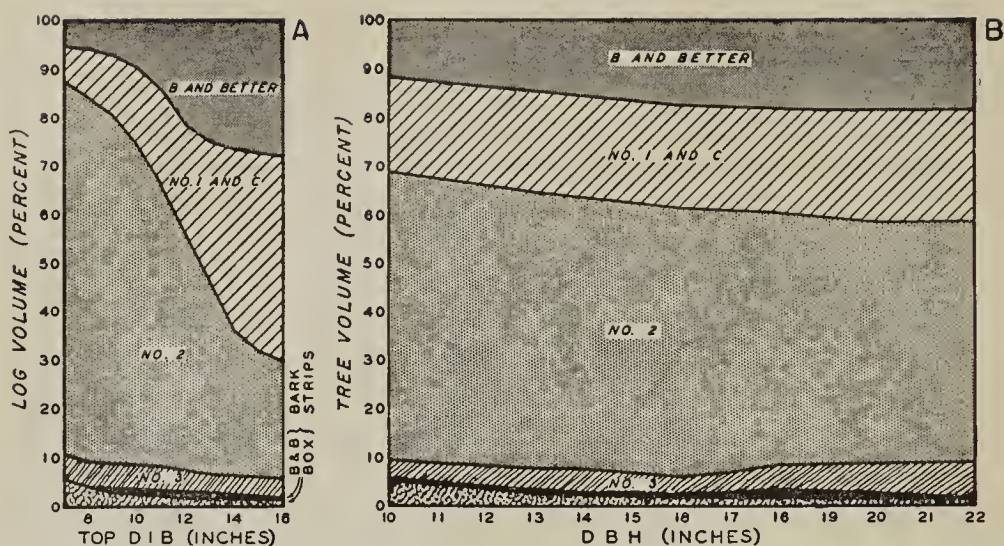


Figure 5.—Percentage of lumber by grades from longleaf logs and trees of different sizes, based on a second cutting in a South Carolina stand logged 40 years previously. (After Garver and Cuno)

petition of mineral substitutes, and a decline in exports during the depression years. For about 4 years (1936-40) the output was also lowered by Government subsidies, under the Agricultural Conservation Program, to maintain prices.

The peak was passed with surprisingly few advances in techniques (except the substitution of cups for boxes). In spite of the size and profitableness of the industry, few people engaged in it received more than a bare livelihood. There was an utter lack of efficient business methods, and antiquated woods practices were common (278, 362). The generous profits from abundant natural resources were not conducive to the conservation of trees. As long as the virgin timber lasted, the industry's methods were wasteful, in contrast to French practice, under which regeneration was provided for and trees were worked 50 years instead of five.⁶

While the virgin timber lasted, nearly all United States gum naval stores came from longleaf pine. At present only about 40 percent comes from longleaf, the rest from slash pine.

The industry is now in its second migration. First it passed through the virgin forest from the Carolinas to Texas just ahead of the loggers. Then it returned to the Atlantic seaboard to repeat the process in second-growth stands. Since the Carolinas could not long meet its renewed demands, leadership in production passed to Georgia and Florida at the turn of the century (Fig. 6). It has not yet been re-established in Louisiana and Texas for lack of enough timber of sufficient size. The stills will reappear there, however, as soon as the trees are large enough. Nevertheless, the industry may never be fully restored west of the Mississippi, where there is no natural reproduction of slash pine to supplement the longleaf output.

⁶Yet the advantages of light chipping were not entirely unknown in the United States, even in the box-cutting days. The use of narrow or low streaks in chipping was advocated (3) as early as 1851 on the ground that yields were as good as from wider cuts. It was recommended that streaks $\frac{1}{2}$ inch deep and $\frac{1}{4}$ inch high be chipped each week with a sharp "hacker." Such suggestions received scant attention for 75 years (621).

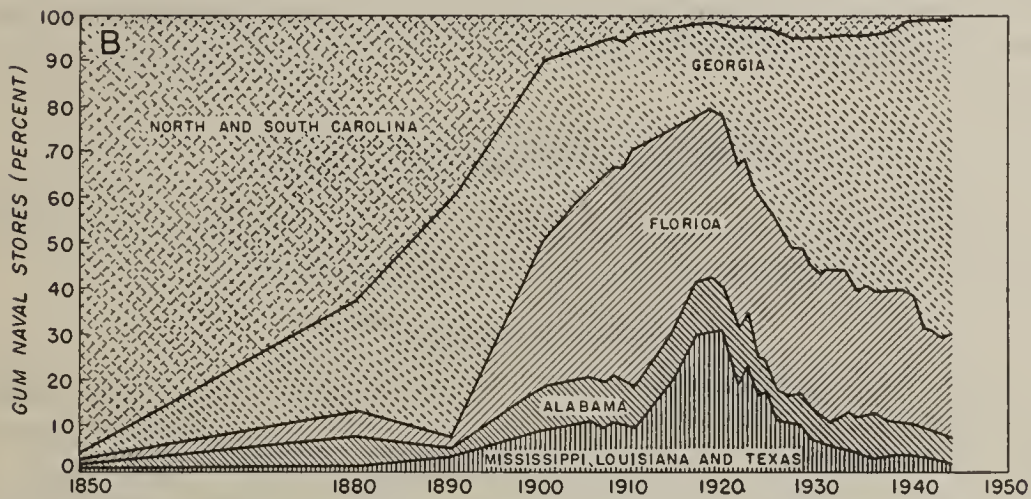
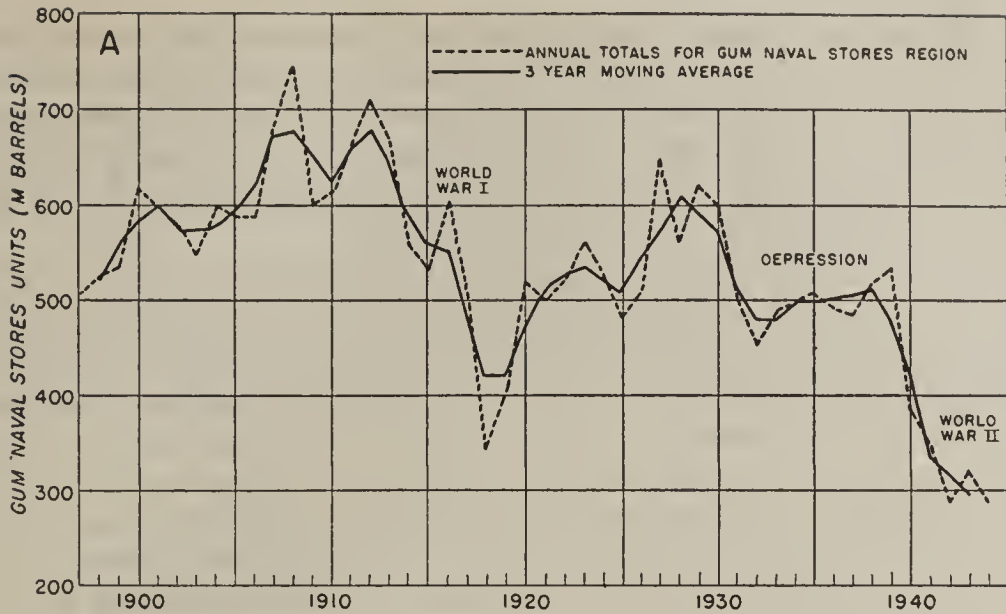


Figure 6.—A, trends in gum naval stores production, and B, division of the total output among States. (Statistics from Thomas Gamble, Savannah, Ga.)

The second decline in the Carolinas was not duplicated in the Gulf Coast States (190), where growing conditions were better. The Gulf States continued to increase production after World War I; activity centered within a radius of 135 miles of Charlton County, Ga. (Fig. 2). In this region there are an estimated 29 million acres of pine woods suitable for turpentine. Of this area 36 percent was being worked for naval stores in 1942, 25 percent was worked out or resting, and 39 percent was stocked with trees too small to work or reserved for future turpentine. Conservation measures and developing forestry practices should permit the Southeast to retain its present leadership in naval stores production.

About 83 percent of all the longleaf and slash pine timber worked for naval stores in 1944 was operated under the terms of the Agricultural Conservation Pro-

gram. This program provided financial incentives to producers for protecting their woods from fire, restricting operations to the larger trees, limiting the number of faces per tree in accordance with its size, leaving a minimum width of bark between faces, working not over 18 inches in height in one season, and ceasing operations at a specified height (49). The producers were granted Federal subsidies for each turpentine face meeting the conservation requirements.

As a result of improved turpentine practices developed by research in recent years, it is estimated that producers of gum naval stores are now getting over a million dollars more revenue annually than they did a few years ago.⁷ The increase is achieved through numerous improvements in equipment, methods of operation, grades of product, and means of storage. Trees are now being chipped more conservatively and fewer small trees are worked. The latest advance has been the application of chemicals to stimulate gum flow. It has also recently been found possible, with the aid of chemicals, to develop methods of chipping that remove only the bark, and hence further conserve the life, growth, and gum-producing power of turpentine trees, as well as their value for lumber and other wood products. If the rapid progress of such research can be maintained, the cost of turpentine should be lowered to a point where it can serve entirely new industrial needs and open new markets.⁸

MINOR COMMERCIAL USES

In addition to the major uses of longleaf pine described above, several important minor commercial uses of this species may be mentioned.

Wood Derivatives⁹

Wood naval stores is an old industry to which longleaf pine continues to make a major contribution. The products of gum and wood naval stores are generally similar and used for the same purposes. Turpentine made from gum may be less uniform than the product of wood distillation, but can be refined to desired specifications by redistillation. Some of the wood naval stores is obtained as a byproduct of the sulphate process of manufacturing pulp, but most is obtained by destructive

⁷Early turpentine practices were so destructive to timber that one company discontinued leasing turpentine rights in longleaf pine (154), resuming work later under restrictions designed to protect the trees. The new rules permitted the hanging of one cup on trees 12 to 16 inches in diameter and two cups on larger trees. They allowed each crop to be worked for two seasons only. This more conservative system was found profitable.

⁸Contrast American production with that of prewar France, where on 2 million acres about one-fourth as much naval stores was produced as on 50 million acres in the United States. This situation is a challenge to American scientists and businessmen (259). At present about 40 commercial uses for turpentine and over 100 for rosin are reported (557).

⁹The nonresinous elements in nearly all kinds of wood are roughly the same. Both hardwoods and softwoods free of extractives contain about 50 percent carbon, 6 percent hydrogen, 41 percent oxygen, 0.1 percent nitrogen, and 0.3 to 1.0 percent ash (261). The ash contains the following ingredients: CaO, 37.2 percent; CO₂, 31.5 percent; K₂O, 10.3 percent; SO₃, 4.3 percent; MgO, 4.2 percent; SiO₂, 3.4 percent; Fe₂O₃, 2.8 percent; P₂O₅, 2.7 percent; Na₂O, 2.3 percent; C, 1.1 percent; and Cl, 0.2 percent (485, 486). The principal components of wood are lignin and cellulose. The composition of cellulose is represented by the formula C₆H₁₀O₅ taken x times. The content of resinous extractives indicates the suitability of wood for naval stores.

distillation or by a steam and solvent process from the seasoned remnants of trees—largely stumps—called fatwood or lightwood.¹⁰

In the destructive distillation of resinous wood the original crude products usually consist of an oily layer of distillate, a watery layer of distillate or pyro-ligneous acid, noncondensable gas, and charcoal. Of chief commercial importance are wood turpentine, pine oil, pine tar, tar oils, and pitch. The constituents of the watery distillate—acetic acid and methanol—occur in such small amounts that their commercial recovery, as a rule, is impractical. The residue in the retort is pine charcoal. Four thousand pounds of wood yield 7 to 12 gallons of spirits of turpentine. Destructive distillation plants operating with stump and top wood produce about 35 gallons of crude pine tars and oils and 345 pounds of charcoal per ton of wood (338).¹¹

The light oils and tar are separated into a variety of products depending on current market conditions. Pine oil is light and straw-colored and has a pleasant odor. Some pine oil, along with turpentine, may be recovered from oils given off in the first stage of distillation.¹²

In the steam and solvent process, the wood is first ground in a machine shredder and then steamed to remove turpentine and pine oil. The pine oil is later separated by distillation, the rosin by first dissolving in gasoline and then distilling the solvent (262).

In 1942, 12 to 15 cars of longleaf stumps were being removed from the Kisatchie National Forest each week, and over \$1,000 a month was being paid out to local labor (Pl. 8). Although stumpage was only 50 to 75 cents per acre, it returned nearly half of the current value of the cut-over land.

In 1934 the Forest Survey found in south Georgia alone about 7-2/3 million tons of merchantable old-growth longleaf stumps suitable for blasting. An additional potential 8 million tons was in unseasoned stumps and in stumps scattered among dense stands of young growth (529). The latter are not available for dis-

¹⁰The forerunner of modern wood distillation was the crude pit process of Colonial days, producing only tar and charcoal. A method of slowly charring fatwood in a woods kiln to obtain tar is described by Michaux (390). Wood yielding 100 or 130 barrels of tar required 8 or 9 days to burn. Pitch is tar reduced by evaporation, preferably not beyond half its original bulk.

The destructive distillation process now consists of heating the wood, usually in a horizontal retort with an opening leading to a condenser, the heat being supplied by a firebox at one or both ends of the retort. The first destructive distillation plants were started before 1880 in North Carolina (177), but until 1908 all rosin and most turpentine were produced from gum. By 1920 the output of the wood naval stores industry was estimated at 10 percent of the national production of naval stores (351), and by 1942 it was 35 percent, largely from steam distillation.

¹¹The following weights and measures of longleaf pine wood and charcoal are given by Brown (51):

Specific gravity of dry wood	0.551
Weight of one cord of dry wood	2463 pounds
Weight of charcoal from 100 pounds of dry wood	23.75 do.
Specific gravity of dry charcoal	0.333
Weight of one bushel of dry charcoal	17.52 pounds
Weight of charcoal from one cord of dry wood	585 do.
Volume of charcoal from one cord of dry wood	33 bushels

¹²Pinene, dipentene, and sylvestrene occur chiefly in the initial oily fractions given off. Resin oil, rosin spirit, rosin oil, wood oil, acetic acid, and acetone are formed somewhat later by the action of heat on the wood substance and on the resinous material remaining in the wood. The principal uses of pine oil are: (1) in the recovery of metals by the flotation process; (2) in paint and varnish; (3) in the manufacture of disinfectants, sanitary deodorants, germicides, and essential oils for perfumes, soaps, and toilet preparations; (4) as a solvent; and (5) as a denaturant for alcohol. It is also a major ingredient in mosquito repellents (78).

tillation, however, since the damage to growing stocks incident to their removal would exceed their return.

Table 7 shows the amount of merchantable stump wood recoverable in 1935 in four survey units in the longleaf pine belt. With a supply in 1935 of nearly 21 million tons of merchantable stumps, an additional 12 million tons of usable stumps, and an annual requirement of only 300 to 350 thousand tons, considerable expansion in the production of wood naval stores is possible.

Table 7.—*Merchantable stump wood on 20 million acres in southern South Carolina, southeastern Georgia, and northern Florida, 1935*¹

Stumps per acre	Rolling uplands	Flatwoods	Swamps, bays, ponds, etc.	Total	Percent of total
<i>Thousand tons</i>					
5 or less.....	239	216	16	471	2.2
6-13	1,445	1,642	53	3,140	15.0
14-25	2,281	3,980	132	6,393	30.5
26 or over.....	2,552	8,248	163	10,963	52.3
Total	6,517	14,086	364	20,967	
Percent of total....	31.1	67.2	1.7		100.0

¹The survey units covered are Florida 1, Georgia 1 and 2, and South Carolina 1 (see Figure 2). In addition to merchantable wood there was a potential supply of 12,469,000 tons for blasting operations, consisting of (1) sound and seasoned stumps so located that large-scale extraction under current practices is not considered practicable, (2) recently cut stumps from old-growth pine that are not yet sufficiently seasoned, and (3) stumps that will result from the felling of old-growth longleaf trees still standing in 1935.

To be merchantable, stumps must be sound, well-seasoned heartwood of longleaf pine in such condition and so located that they can be either pulled by machines or removed with explosives. The amounts given in Table 7 are based on the removal of the stumps by blasting; if the stumps are pulled rather than blasted, the amount of wood recovered per stump is increased by 60 percent. Stump-pulling operations are at present confined largely to the flatwoods because of the need for heavy machinery. Even in the flatwoods, stumps are pulled only in well blocked-out areas of considerable extent that are accessible to railroad transportation (567).

Charred longleaf stumps and residual wood chips from the distillation industry cannot now be economically used as pulpwood. However, some engineers see no fundamental reason why paper could not be made as a byproduct of the wood naval stores industry (77, 78). Conversely, naval stores can be derived as a byproduct of the kraft pulp mills. Sulphate wood turpentine is recovered by condensing the vapors released from the pulping digesters. In this process, soapy curds, consisting of mixed resin and fatty acids, float on the spent cooking liquor, called black liquor. This is treated to recover talleol or liquid rosin (232, 557).

Needle Products

Among numerous byproducts of the longleaf forest are pine-needle oil and other industrial or medicinal compounds. Steam distillation of green needles yields an oil of balsamic odor, distinct from the pine oil made by steam distillation of stump wood. The foliage from young trees is richest in oil, the average yield being 0.42 percent of the weight of the fresh leaves.¹³ Slash pine, incidentally, yields only 0.27

¹³The larger and more numerous the foliar resin ducts, the greater is the yield. Specific gravity of pine-needle oil ranges from 0.8829 to 0.8849.

percent. The principal constituents are camphene, beta pinene, cadinene, and borneol. The pleasing scent is due mainly to borneol and its acetic ester (483).

The long and fibrous longleaf needles are suitable for weaving into baskets and mats. These, together with pine cones, find considerable ornamental use (19). Longleaf pine plumes, palmetto and other green plants are shipped north for the Christmas trade (18). Indeed, the popularity of longleaf sapling decorations at one time threatened the life of this species in certain sections of the South (73).

Longleaf needle fiber, processed from fallen pine straw, may be made into pine wool, an inexpensive upholstery material.¹⁴ It can also be used as a surgical dressing. The cost in 1935 of collecting a ton of needles from 2 or 3 acres was 50 cents. About 2 tons of raw material, or 1½ tons of clean needles, make 1 ton of finished product. Fresh, clean needles, which fall in abundance on burned areas, are preferred.¹⁵

Longleaf pine straw has been processed in Mississippi for use as a sanitary litter for poultry houses. Dry needles, together with a few green cones for each ton of straw, are placed in a machine which chops the material into pieces about one inch long. Shorter pieces, dust, and trash are blown out by a fanning mill. The straw is then disinfected by an oily mist, perfumed by pine oil from fragments of the green cones, and conveyed to a bin.¹⁶ The resulting aromatic litter absorbs moisture without becoming matted and counteracts unpleasant odors. Discarded after a week or two of use, the litter may be composted into fertilizer. Sometimes the straw is raked up twice a year and used for fertilizer on cotton fields or as bedding for horses and cattle (139).

THE WOOD AND ITS ELEMENTS

Can the widespread use and vaunted superiority of longleaf pine be attributed merely to an abundant supply of cheap raw materials, or does the wood possess intrinsic advantages over other southern pines?

The early prejudice against lumber from turpentine longleaf pines was discredited by research at the end of the 19th century (174). It was found that timber from turpentine trees is as strong as or stronger than from unworked trees, that worked timber of the same weight is as strong as unworked, and that weight, shrinkage, and durability of the heartwood are not affected by turpentine.

The weight of longleaf wood affects not only its strength but also the ease of handling in transportation from woods to mill. A cord of green wood weighs about 4,000 to 4,200 pounds. The weight of 1,000 board feet log scale of green long-

¹⁴The process is as follows: Pine straw mixed with flakes of caustic soda is packed in an 8- by 12-foot perforated metal cylinder, and in a large retort is subjected to 30 pounds of steam pressure for about an hour. The treated needles, now blacker and less brittle, are torn to shreds on the nail-studded drum of a coarse carder, and then washed. The torn needles are next passed through a second and a third finer carding machine, each time being torn into finer strands and rewashed in water. A centrifuge removes excess water before the fourth carding and drying. The resilient and excelsior-like product is pressed into bales and shipped to mattress makers and upholsterers (440).

¹⁵The annual needle fall in unburned second-growth stands of slash and longleaf pine is from 2,400 to 3,500 pounds per acre; some 20,000 to 55,000 pounds per acre may accumulate in forests protected from fire for 10 years or longer, after which little or no further increase occurs (287).

¹⁶This process adds a value of \$10 per ton to raw materials costing about \$5 a ton (495).

leaf pine is greater for small than for large logs, because of a higher proportion of sapwood and a greater percentage of waste in milling; also, if the Doyle rule is used, the exact yield in board feet is not given as closely for small as for the larger logs. Thus, the weight of 1,000 board feet (Doyle scale) of longleaf pine is about 11,000 pounds for green 12-inch logs, 7,700 pounds for 18-inch logs, and 6,500 pounds for 24-inch logs. Air-dry weight of logs or other rough products is about 88 percent of green weight.

Wood Fibers

The fibers of longleaf are rather long, averaging 3.7 mm. (218). Summerwood tracheids are usually very pointed and shorter than those in springwood of the same growth ring. Shepard and Bailey (496) found that in the cross section of a stem the tracheids increase in length for a few decades until a maximum is reached, after which the average length fluctuates over a relatively narrow range. Length of fibers increases rapidly during the first 20 years of a tree's life. Between 10 and 40 years the average length increases from $2\frac{1}{2}$ to 4 mm., and beyond 40 years from 4 to 5 mm. A maximum average length of 5.08 mm. is reached at about 160 years (Fig. 7, A).

Wide-ringed wood from young trees usually has short, narrow, thin-walled tracheids. There is no marked relation between width of ring and length of tracheid. Tracheids in springwood have more bordered pits than those in summerwood (203). Both tracheids and parenchyma are found in wood rays, which, according to Myer (403), average 7.8 percent of wood volume for conifers in general, and 8.3 percent for longleaf pine.

More important in pulping, perhaps, is the width, rigidity, and abundance of fibers. Tracheids in the stem become narrower with elevation. They also tend to be smaller in stunted than in thrifty trees. Cell walls are from 3 to $3\frac{1}{2}$ microns thick in springwood, and 6 to 7 microns thick in summerwood, but the cells themselves are only about half as wide radially in summerwood as in springwood. Thus material with 50 percent summerwood (per linear unit) has about twice as many thick-walled as thin-walled fibers (Pl. 9).

STRENGTH AND RELATED FACTORS

Among southern pines, longleaf is exceeded only by slash in weight and specific gravity. Volumetric shrinkage of longleaf is slightly, but not significantly, less than for slash, shortleaf, or loblolly pines. In composite-strength properties, longleaf is often inferior to slash but superior to all other southern pines (378). An investigation of this problem was made by Kuehn (332). He found no appreciable difference between longleaf and slash pine wood (green, air-dried, or steamed) in toughness, static bending, and compression. With lower specific gravity and moisture content, the wood of slash pine was as tough as that of longleaf. He concluded, therefore, that slash is potentially as good a structural timber as longleaf pine. Brust and Berkeley (57) found that longleaf pine containing about 30 percent summerwood was as strong as loblolly with about 50 percent summerwood. The supposedly inherent superiority of longleaf wood, however, may well be doubted. The frequent superiority in

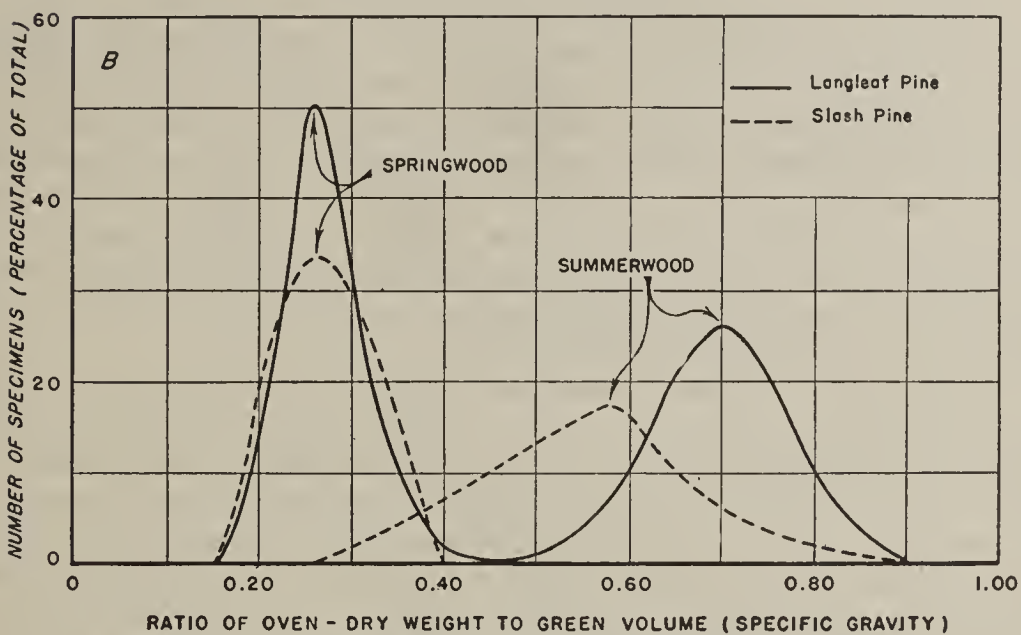
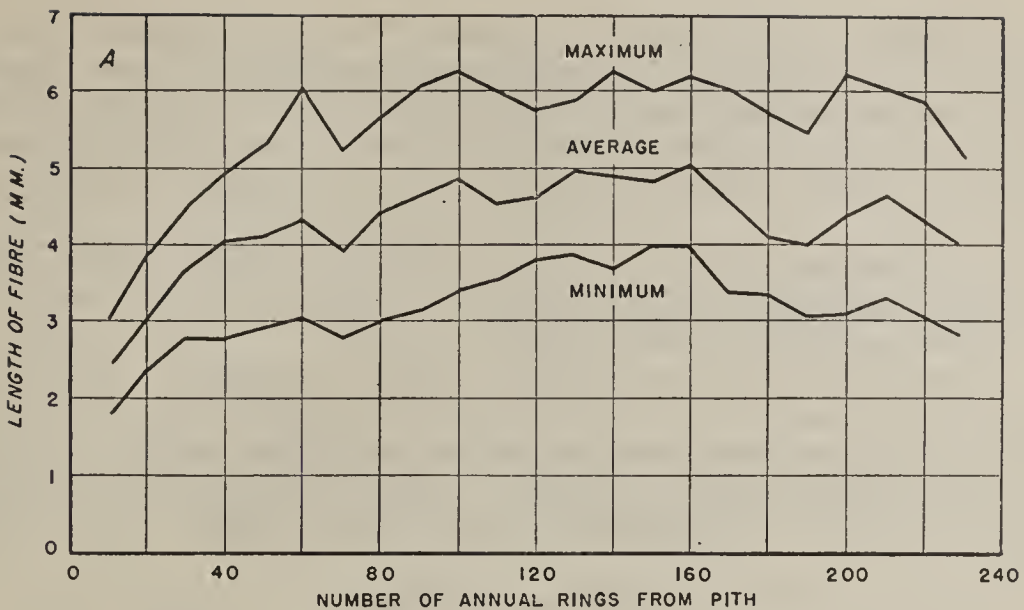


Figure 7.—A, variations in length of longleaf fiber; B, variations in density of longleaf and slash pine wood. (After Shepard and Bailey)

weight and strength may be controlled by environmental factors rather than by inheritable peculiarities.

Specific Gravity and Strength

The specific gravity of all species of wood substance exclusive of air spaces is about 1.5. Dry southern pine floats because the cell cavities and pores contain air. Specific gravity roughly measures the strength of wood. A cubic foot of longleaf wood weighs about 55 pounds in the green state and 39 pounds after kiln drying to about 8-percent moisture. The specific gravity of longleaf averages about 0.58 at 12-percent moisture (average air-dry condition), or 0.62 when oven dry.

The weight, strength, and related qualities of clear, dry, longleaf wood are influenced by the proportion of thick-walled summer tracheids and thin-walled spring cells. Hardness, heaviness, density, and strength are closely associated so that the percentage of summerwood may be used as an indicator of them all.¹⁷ Measurements of various elements of strength in longleaf pine wood are shown in Appendix table IV-a.

The springwood in all four principal species of southern pine is quite similar in density, with a minimum of 0.15 and a maximum of 0.40-0.50, averaging 0.28 for longleaf and 0.275 for slash pine (429).

Summerwood is from 2 to 2½ times as dense as springwood. Also, it varies more in density than does springwood in southern pines (Fig. 7, B). Longleaf has not only the heaviest summerwood, but also the most distinct seasonal banding within the annual rings. The effect of high summerwood content on strength is reduced somewhat where the color distinction between spring and summer portions of rings is poor.

Moisture Relations

Fresh sapwood usually contains three to five times as much water as does heartwood. No appreciable changes in size, shape, and strength of wood are associated with moisture content above the so-called fiber-saturation point, but drying below this point produces some shrinkage, occasional distortion, and definite increases in strength. The moisture content of live sapwood is greater than that of green heartwood. At the fiber-saturation point, which occurs at 18- to 26-percent moisture, the cell walls are saturated throughout, but the cavities of the fibers are essentially free from moisture (379). Below the fiber-saturation point, moisture content and the logarithms of corresponding strength values conform closely to a straight-line relationship for any species and property¹⁸ (Fig. 8).

Toughness may be lost in drying as it depends upon flexibility as well as strength. The influence of moisture content on toughness and other aspects of shock resistance is variable: some of these properties may increase, decrease, or remain unchanged during drying. Although an increase in strength is generally attained as timber seasons, it is not safe to rely on this where the timber may reabsorb moisture and thereby lose strength. Dry wood is much stronger than wet wood, but dry wood returned to the wet condition is weaker than it was in the original green state. Thus tests which subjected longleaf pine to repeated soaking and redrying showed increased compressibility and lower resistance (552). Such deterioration need be considered, however, only when the wood is to be exposed to pronounced changes in moisture content while in service.

¹⁷The common opinion that longleaf pine with a large number of rings per inch is always dense and strong is incorrect; see Plate 9.

¹⁸This relationship may be written: $\log S = \log S_p + K (M_p - M)$ where S equals strength value from test at moisture content M , S_p equals strength value of green wood at moisture content M_p , the intersection point (fiber saturation), and K is a constant, a positive value representing the negative slope of the inclined line that shows the variation of strength with moisture content. The algebraic sign is minus for properties that increase with loss in moisture (607). The agreement of strength-moisture data with this exponential formula justifies the conclusion that if K and M_p have proper values, the formula will represent accurately the relation between moisture content and any mechanical property of wood, regardless of species.

The resistance of longleaf pine wood to crushing, as influenced by moisture and specific gravity, is shown in Appendix table IV-c.

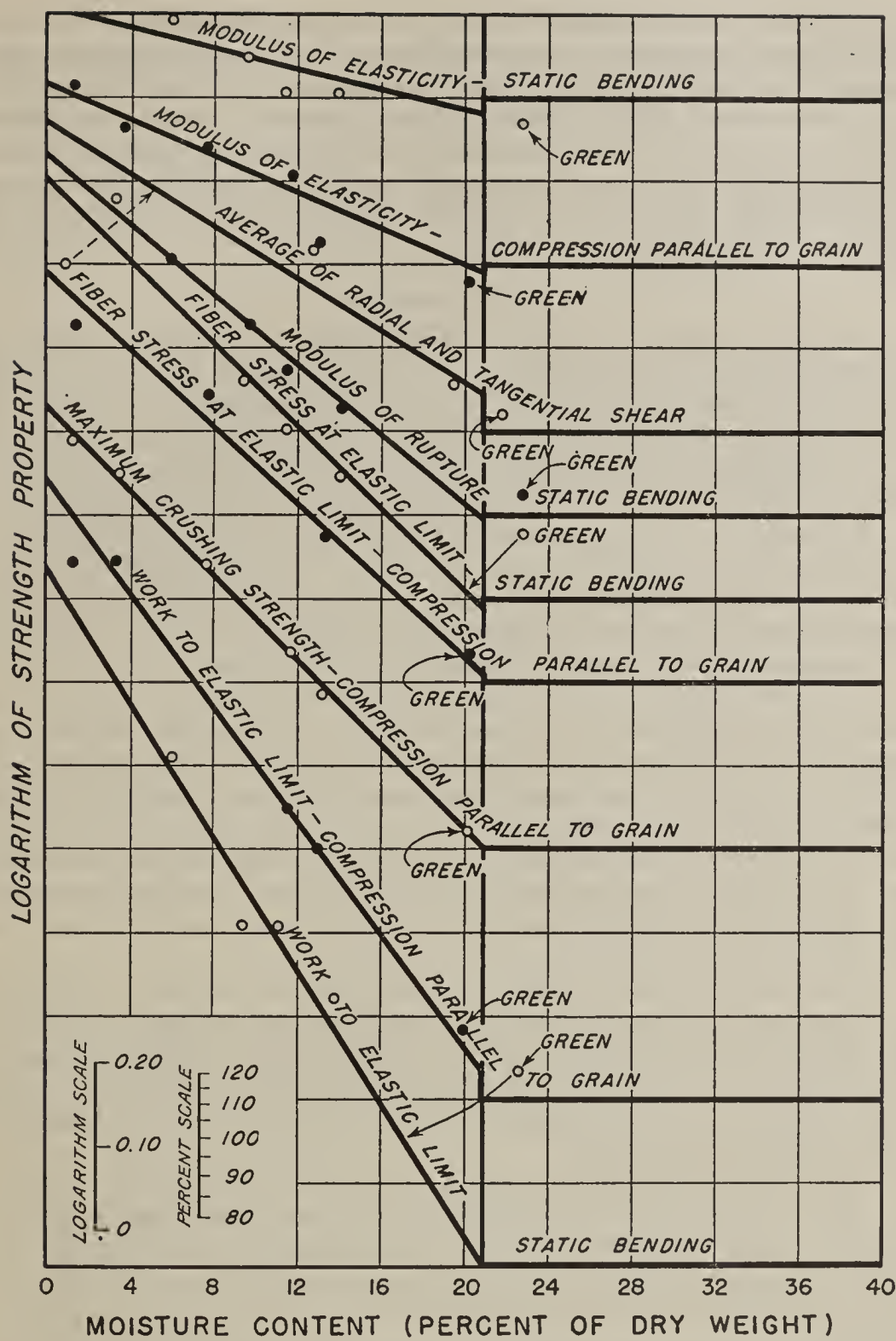


Figure 8.—Strength-moisture relations for 2- by 2-inch longleaf pine specimens. Horizontal portions of curves represent control specimens soaked to raise them above fiber-saturation point. Points labeled "green" represent specimens tested as soon as received at the laboratory. (After Wilson and Tiemann)

As a rule, consumers should consider only average moisture conditions and strength values in the green or average air-dry state. It is sometimes desirable, however, to adjust strength values at one moisture content to what they would be under some other condition. Average changes in strength effected by varying the moisture content by 1 percent are from 0.5 to 8 percent of the various properties.¹⁹ Increase in strength with drying is more pronounced in small, clear specimens than in large timbers containing defects. In the latter the added strength may be offset by the defects that develop in seasoning.

Growth Relations

Because silviculture offers a means of modifying rates of growth through tree selection and control of stand density, it is advantageous to know how growing conditions affect the quality of wood. If properly planned, thinnings can anticipate and avoid the reduced growth in crowded stands, thus producing more even-grained wood. When growth is not uniform it is profitable to know which trees or parts of trees contain inferior wood so that they can be sold for the less exacting uses.

As already noted, the percentage of summerwood, not the width of rings, is the visual criterion of specific gravity. In straight, uniformly grown trees with an even ring structure, the amount of summerwood is a reliable index of strength, but timbers showing irregular rates of growth and variable rings should be viewed with suspicion regardless of the amount of summerwood they contain.

Old-growth longleaf wood is fairly uniform in weight and strength for some distance from the pith; but weight and strength may decrease as the bark is approached. The outermost layers are often relatively weak. Second growth is normally lighter and weaker near the pith than toward the bark. Wood from both old-growth and second-growth trees tends to be weaker in the upper than in the lower portions of the stem.²⁰ Wood from a residual virgin forest that has been released from competition and has continued its development with second-growth stands is not typical of either condition. Each tree reflects certain past changes in its environment and has its own strength pattern.

Because rapidly grown trees often contain nearly twice as much summerwood near the butt as in the upper parts, the quality of long timbers should be judged by the rings at the top rather than at the butt. Density decreases significantly from the butt to the top of the tree. Old-growth longleaf is about 45 to 50 percent summerwood at the butt, 35 to 40 percent at a height of 31 to 40 feet above the ground, and 30 to 35 percent at 61 to 70 feet.

Three principal types of wood have been traced to certain growing conditions: (1) wood of light weight from rapidly growing young trees having large, wide-spreading crowns; (2) heavy, dense wood of medium growth rate from fairly close stands with somewhat restricted crown development; and (3) wood of light weight and extremely slow growth from the outer portion of certain trees growing for a long

¹⁹See parenthetical figures in Appendix table IV-a. Where the approximate corrections based on these simple linear relations are not sufficiently precise, the formula from footnote 18 may be applied.

²⁰While the strength of wood varies with its location within the bole as indicated, the position is not itself a reliable guide to strength. Wood from young trees may or may not be weaker than that from old trees; heartwood is not intrinsically stronger than sapwood; and no consistent relationship exists between strength and the width of annual rings.

time under great competition (422). Type 2 is illustrated in Plate 10, *A* and *B*, and type 3 in Plate 10, *C* and *D*. Type 3 has little or no summerwood and may be found on very adverse sites in trees growing for a long time under great competition (422).²¹

Certain defects are related to position within a tree and to rate of growth. Samples taken adjacent to the pith show greatest cupping in slow-growing trees, less in trees of medium growth, and least in trees of rapid growth. On the other hand, cross sections from trees of rapid growth have the greatest tangential shrinkage, indicative of checking.

Heartwood begins to form in longleaf pine at about 20 years. Old-growth sapwood is rarely more than 2 or 3 inches wide, narrower than in other southern pines. In fast-growing trees the band of sapwood remains relatively wide at 30 years. One investigation showed that in Texas virgin longleaf less than 130 years old contained the highest percentage of heartwood at the top of the second log (Fig. 9, *A*). In trees 130 to 230 years old, heartwood content decreased with height above ground and increased with diameter at breast height.²²

At stump level, the heartwood content is usually lower in open-grown than in forest-grown trees. With fast growth, volume accretion tends to outstrip heartwood formation, or at least to decrease the rate at which the band of sapwood becomes narrower. Hence turpentineing, by retarding growth, increases the proportionate volume of heartwood by 5 to 12 percent.²³

The so-called compression wood or red wood is undesirable for both lumber and cellulose uses.²⁴ Such wood has relatively wide annual rings and a lifeless appearance. Cells are nearly circular in cross section instead of rectangular or polygonal, and, unlike most wood, the cell walls have many spiral checks and striations. There is more lignin and less cellulose than in normal wood. Also summerwood is opaque rather than translucent in cross sections $\frac{1}{8}$ to $\frac{3}{16}$ inch thick.

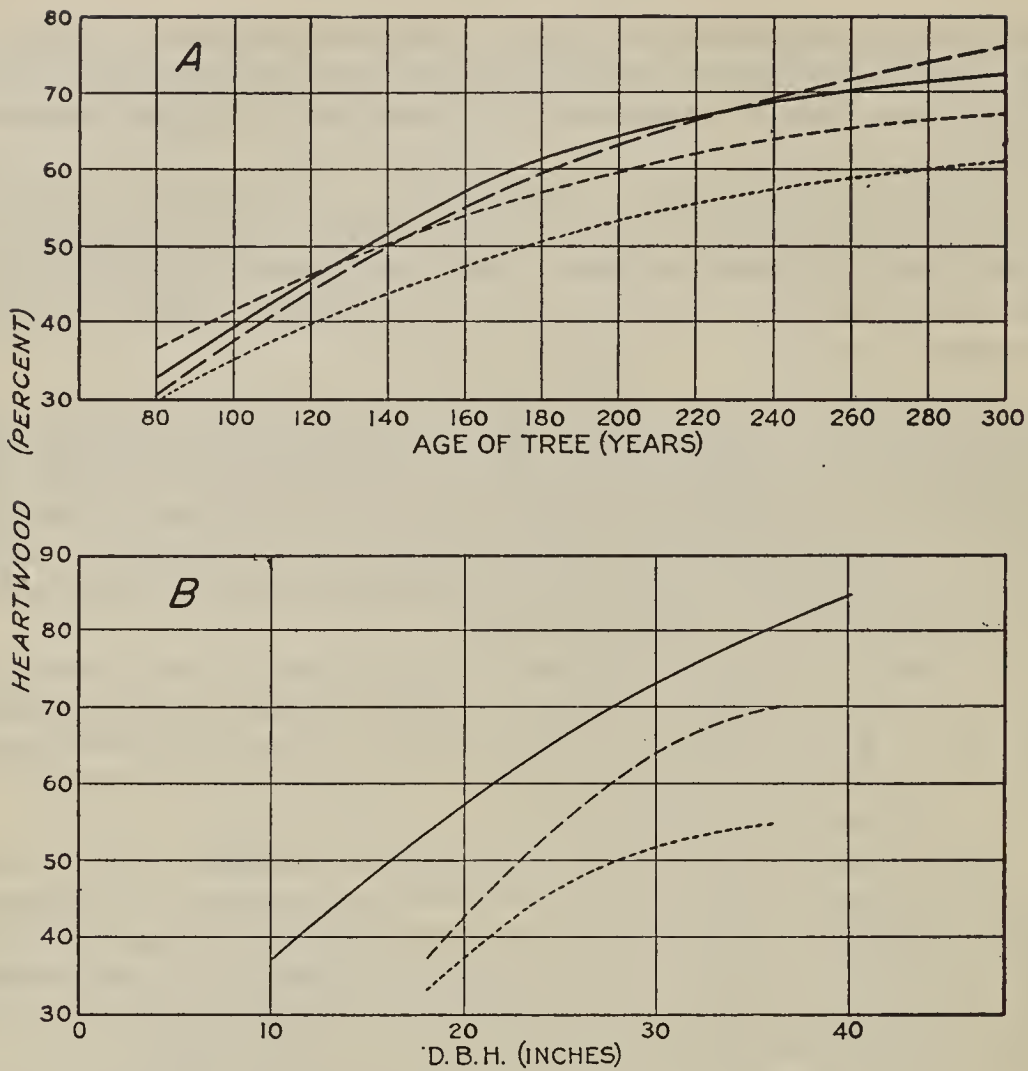
Compression wood, which occurs mostly in leaning trees left after a windstorm, is frequently above average in weight, and, allowing for its greater density, weaker

²¹Although the study from which these data were obtained was confined to the former Choctawhatchee National Forest, in Florida, the results are believed applicable over a considerably wider area. In another study on deep, sterile sands, Lodewick (354) found a smaller percentage of summerwood near the pith, and saplings and the tops of larger trees were least able to maintain late season growth. Only beyond the eighth ring from the pith could the relationship between ring width and width of summerwood be expressed by straight lines with positive slopes. The trees from dense stands attained a maximum percentage of summerwood nearly 3 percent greater than did trees from the less dense stands. The densest wood had rings 0.5 mm. wide. The open stands maintained a maximum percentage of summerwood in rings appreciably wider than those containing most summerwood in the denser stands.

²²For trees of similar age, longleaf and slash pines usually contain more heartwood than do shortleaf and loblolly, but the amount of heartwood is neither a characteristic of the species nor solely a function of the age of the tree, though it is related to rate of growth. Of the total number of rings, old trees contain a larger proportion in sapwood than young trees, but of the total radius old trees contain a smaller proportion in sapwood than young trees, owing to the fact that many old trees have a thin band of sapwood containing relatively narrow rings.

²³The percentage of tree volume in heartwood at 50 and 100 years, compared for 42 round and 81 worked longleaf pines taken from a Florida stand, ranged from 9 to 23 percent in round timber and from 21 to 28 percent in worked timber (151).

²⁴Formation of such wood is related less to seasonal changes in growth than to differences in rate of diameter growth in opposite parts of the trunk. Oval sections of stems with eccentric rings are likely to contain compression wood where the rings are widest.



CROSS SECTIONS:

- | | |
|----------------------|------------------------|
| —— At stump height | ---- Top of second log |
| - - Top of first log | Top of third log |

Figure 9.—Percentage of heartwood at various heights from the ground. A, in relation to age of tree, and B, in relation to d.b.h.

than normal wood. Longitudinal shrinkage is highly variable and greater than in normal wood, while transverse shrinkage is somewhat less. (Compression wood shrinks radially only half as much as normal wood and tangentially about a third as much.) As might be expected, compression wood is above normal in resistance to crushing, whereas its resistance to static bending is only about three-quarters of normal (378). The bowing and twisting of manufactured pieces is excessive. As most of this inferior wood is formed after, rather than before a stand is logged (Fig. 10), it seems to be associated with accelerated growth.

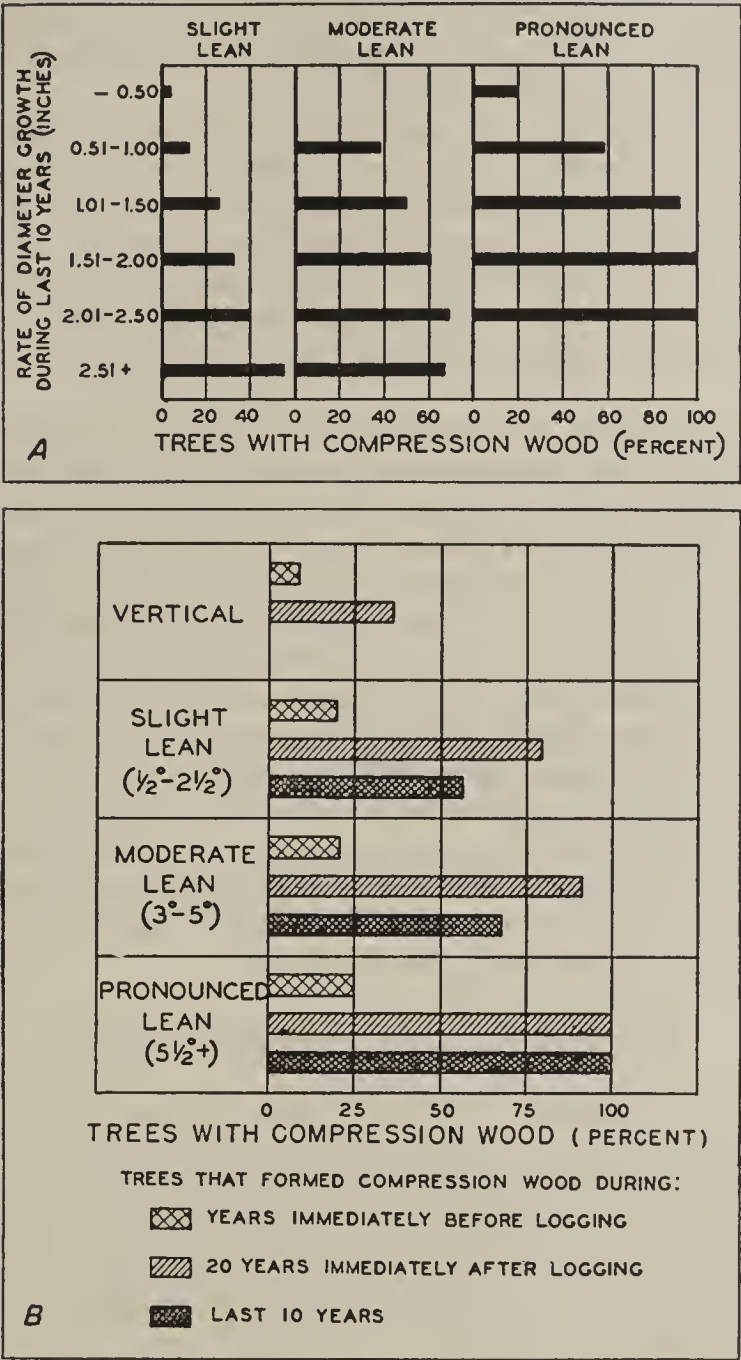


Figure 10.—Proportion of leaning longleaf and loblolly pines containing compression wood as affected by A, rate of growth, and B, degree of lean and time of release by logging.

GRADES AND DEFECTS

In grading southern pine for structural use, the proportion of summerwood is a criterion of quality. Under the rules of the American Society for Testing Materials, southern yellow pine lumber, to qualify as "dense," must average at least six annual rings per inch at either end, and in addition, one-third or more summerwood over a 3-inch portion of a radial line or lines, representing average growth on the

cross section. Summerwood and springwood must contrast sharply in color; the summerwood must be dark except in pieces having considerably more than the minimum requirement of summerwood.²⁵

According to the grading rules issued by the Southern Pine Association in 1939, "longleaf yellow pine" lumber must be true to species (*Pinus palustris*) and pass the density requirement. If a specimen does not have the required density, it is not regarded as longleaf, though it may have come from a longleaf tree. The bulk of southern pine, however, is graded by yard-lumber rules in which the proportion of summerwood is not a criterion of quality. In yard lumber, quality is lowered²⁶ by knots and blemishes that weaken the wood, decrease workability, and detract from appearance.

Southern pine timbers were first graded on the basis of durability rather than strength and defects. Railroads specified, for instance, the "heart grade" of longleaf for bridge and trestle timbers. "All-heart" material was once in great demand. Now, except where the decay hazard is classed as medium, the superior resistance of heartwood to fungus is no longer important. In low-hazard uses, as in residential construction, sapwood is as good as heartwood, and for unusual hazards like piling both types of wood need preservative treatment. Thus in grading timbers for creosoting, or for use in unexposed situations, only intrinsic strength and common defects need be recognized. To insure strength for structural purposes, timbers should meet the density rule for southern pine (Appendix III).

Large timbers are only about two-thirds to three-fourths as strong as the tests of small, clear samples indicate. Laboratory strength tests on small standardized pieces must be corrected for estimates of timber strength in structural sizes. The strength ratio of a grade represents strength after deduction for the maximum effect of the defects permitted by grading rules. (See Table 8.)²⁷

SEASONING AND PRESERVATION

The volumetric shrinkage of sapwood is about the same as that of heartwood. Shrinkage in the tangential direction is about $1\frac{1}{2}$ times as great as in the radial direction (Table 9). This sets up internal stress in the larger pieces—very thick plain-sawed or box-heart pieces—but distortion and checking are not serious in lumber free from compression wood and properly handled during seasoning and storage.

The suitability of seasoned wood for certain purposes depends on freedom from warping and shrinkage. Departures from original form and size, for example, cause least trouble when parts are cut to fit at the correct moisture content. For

²⁵The A. S. T. M. rule for dense longleaf pine is given in Appendix III.

²⁶Extensive pitch pockets and streaks $\frac{1}{2}$ inch thick and 3 to 4 inches long have been traced to sap-sucker wounds throughout the longleaf pine range. Black stains nearest the wound and lighter stains extending along the grain shade off into fat streaks which may permeate many layers of wood and extend far up and down the grain (360).

²⁷Research workers in recent years (608) have analyzed the influence of these defects. Data for shakes and checks, wane and cross grain, and knots of all sizes, and for the location of such defects in relation to faces of various widths, are available for estimating strength of beams, stringers, joists and planks from the comparable clear, green wood. Basic stresses may be used in computing working stresses for any well-defined grade (Table 8). These stresses apply only to wood that is continuously dry. If other conditions of exposure exist, either the size of the member may be increased or the working stresses decreased to compensate for anticipated loss of strength from decay.

Table 8.—Strength ratios for longleaf pine structural-timber grades with basic stresses, and working stresses recommended by the Southern Pine Association, for material used where it will be continuously dry (608)

Product, type of stress, and strength ratio	Basic stress for clear, dense southern yellow pine	Structural-timber grades ¹				
		Select	Prime	Merchantable	Square edge and sound	No. 1
Beams and stringers:						
Stress in extreme fiber—Lbs. per sq. in.	2,333	—	—	—	—	—
Strength ratio—Percent	—	86	76	69	69	60
Working stress—Lbs. per sq. in.	—	2,000	1,800	1,600	1,600	1,400
Stress in horizontal shear—do.						
Strength ratio—Percent	171	—	—	—	—	—
Working stress—Lbs. per sq. in.	—	67	67	67	67	56
	—	125	125	125	125	105
Joist and plank:						
Stress in extreme fiber—do.	2,333	—	—	—	—	—
Strength ratio—Percent	—	—	67	65	65	—
Working stress—Lbs. per sq. in.	—	—	1,800	1,600	1,600	—
Stress in horizontal shear—do.						
Strength ratio—Percent	171	—	—	—	—	—
Working stress—Lbs. per sq. in.	—	—	67	67	56	—
	—	—	125	125	—	—
Posts and timbers:						
Compression parallel to grain—do.	1,711	—	—	—	—	—
Strength ratio—Percent	—	86	77	70	70	60
Working stress—Lbs. per sq. in.	—	1,450	1,300	1,200	1,200	1,000
Stress in compression perpendicular to grain—do.						
	380	380	380	380	380	380
Modulus of elasticity—do.	1,600,000	1,600,000	1,600,000	1,600,000	1,600,000	1,600,000

¹Southern Pine Association Standards of Sept. 1, 1932. Dense material is required in all the grades named. Cluster knots in groups are not prohibited. Material up to 5 inches thick is graded as joist and plank.

Under W.P.B. Directive 29, "National Emergency Specifications for the Design, Fabrication, and Erection of Stress Grade Lumber and Its Fastenings for Buildings," August 9, 1943, higher stresses are made mandatory under certain circumstances and conditions.

interior finish and flooring in the longleaf region the desirable moisture content is about 11 percent.

Drying

Heavy longleaf timbers air dry slowly. Specimens 10 by 12 inches in cross section still contained 35 percent moisture after drying for 1 year in Washington, D. C. Others, measuring 12 by 12 and 18 by 16 inches, averaged 23 percent after 2 years of air drying, the center containing 26 percent moisture. Some of these timbers showed a tendency in drying to form checks that later might lead to failure by longi-

Table 9.—Estimated shrinkage values in drying of longleaf pine (565)

Dimension	Shrinkage (percent of dimension when green) from green to—		
	Air dried to 12- to 15-percent moisture ¹	Kiln dried to 6- to 7-percent moisture ²	Oven dried to 0-percent moisture (test)
	Percent	Percent	Percent
Radial	2.6	3.8	5.1
Tangential	3.8	5.6	7.5
Volumetric	6.1	9.2	12.2

¹Shrinkage values in this column have been taken as one-half the shrinkage to the oven-dry condition as given in the third column.

²Shrinkage values in this column have been taken as three-fourths the shrinkage to the oven-dry condition as given in the third column.

tudinal shear. Damage from shrinkage often can be reduced by proper storage, avoiding too rapid drying.

In air drying, the weight of a thousand board feet of green lumber drops from about 4,580 to 3,230 pounds (327).

Kiln drying accelerates and controls the seasoning process. At present, clear longleaf is kiln-dried on about an 8-day schedule, but chemical seasoning, using about 40 pounds of urea per thousand board feet, promises to cut this time in half. The presence of a hygroscopic chemical, urea, in the outer portions of the wood permits more rapid drying because it inhibits checking. Urea does not corrode metals, dull tools, or interfere with preservative treatments. It tends to retard combustion. Some 60 to 80 pounds of urea per thousand board feet have been recommended to protect air-dried poles against checking (29).²⁸

Mold and Stain

Wood-staining fungi usually do not appreciably weaken longleaf pine except in toughness. A recent study by Chapman and Scheffer (89) shows that fully developed blue stain damages the wood, specific gravity being reduced 1 or 2 percent, compression strength parallel to the grain and modulus of rupture 1 to 5 percent, surface hardness 2 to 10 percent, and toughness 15 to 30 percent.

Freshly cut lumber should have preseasoning treatment to protect it from blue stain, other fungus discolorations, and incipient decay while drying. Under average drying conditions, stain may develop in the first 30 days of seasoning, and absence of protection may degrade the wood. Fortunately, inexpensive control is afforded by dipping lumber in solutions of organic mercury and chlorinated phenol compounds (482). Mold and stain fungi attack all southern pines and the treatments are the same for all species.

Preservation

The relative durability of untreated longleaf wood is as follows: sapwood, highly perishable; heartwood, moderately long lasting; and very resinous heartwood (known as lightwood or fatwood), highly resistant to most common deterioration agents.

Heavy resinous wood, especially heartwood, has relatively strong resistance to decay. There is some doubt whether dense heartwood is more durable than wood of low specific gravity, but sapwood is certainly perishable when it comes in contact with water or moist soil. Resin helps to exclude the moisture essential to decay (305).²⁹ Resistance of resinous wood to decay varies with moisture content, duration of exposure, and kind of fungus.

Very resinous wood may repel termites but not marine borers; hence, untreated piling along the Gulf Coast, for example, usually lasts less than 1 year. Untreated

²⁸The most recent work in which the full strength and associated properties of green and dry longleaf wood from various southern States were tested was reported by Markwardt and Wilson (379) in 1935 (Appendix table IV-a). All specimens came from trees botanically identified, thus adding to the authenticity of the results. Not only moisture content, but also rings per inch, percentage of summerwood, and density of test materials are given.

²⁹Resin content, however, must be rather high to afford much resistance to wood-rotting fungi. Specimens tested for susceptibility to fungi did not show particularly high resistance to infection by decay even in wood containing 8 to 12 percent resin.

poles and ties, even those properly tie plated, last only 6 to 10 years, or less. The life of untreated lumber subjected to decay in use is scarcely longer. In fact, wherever the hazard from decay, termites, or marine borers is high, the need for preservative treatment is indicated, the quantity and character of preservative depending on the proposed use.

The various wood elements differ in their ability to absorb oils. Generally summerwood is more easily penetrated than springwood, yet both are often very resistant in heartwood timbers. The resin ducts in pine wood rays facilitate creosote penetration.

Longleaf sapwood is relatively easy to treat, but large pieces of heartwood are difficult to impregnate because liquid preservatives penetrate the wood in a longitudinal direction only. In small pieces, such as paving blocks, the heartwood is readily impregnated in pressure treatments. Six or 7 pounds of creosote per cubic foot is low for sapwood railroad ties, but may prolong their life to 20 years.

When a net retention of about 10 pounds of preservative per cubic foot is satisfactory, the usual steaming and vacuum process of conditioning green pine is appropriate. Larger amounts can be injected into round green material, but air drying is an important aid when high absorptions are desired. Much preservative, for example, is needed in piles subjected to the attacks of marine borers in warm climates (374). On the Gulf Coast, well-treated piles usually last 20 years or longer. A creosoted pile trestle 7 miles long, built over Lake Pontchartrain near New Orleans in 1884, was reported in 1930 to contain over 80 percent of the original longleaf pine timbers.

The cost of preservative treatment of longleaf wood may be reduced by mixing petroleum oil or coal tar with creosote. The addition of tar tends to retard penetration of creosote, but this difficulty often can be overcome by increasing treating pressures and temperatures.³⁰ Creosote-petroleum mixtures or preservative salts are widely used to reduce the cost of preservative treatment.

Paint Retention

Resin may adversely affect the durability of paint on wood. It is reported (54) that paints containing zinc oxide are not as durable on resinous woods as on those of similar density and ring width that contain little resin. White lead paint, however, seems to do as well on resinous as on nonresinous lumber. Because turpentine evaporates from wood during seasoning much less rapidly than water, there is sometimes enough left to react on the wood. With a low turpentine content, resin is not fluid enough to exude under ordinary conditions of exposure, but rosin acids, such as abietic and pimaric, which are soluble in oils commonly used in paint, may cause trouble. Thoroughly seasoned wood is most satisfactorily painted.

In its capacity to hold paint, longleaf is not significantly different from other southern pines. Paint lasts better on woods of low density and narrow growth rings (high ring count) than on woods of high density and wide rings. Paint flakes off most where the summerwood bands are widest and on the flat-grain portions of

³⁰The Forest Products Laboratory, Madison, Wis., can supply detailed information on problems and methods of wood preservation.

boards. Priming coats, rich in turpentine, decrease the durability of paint on southern pine. Aluminum paint as a priming coat offers the best means so far discovered for increasing the life of paint.

PULPING PROPERTIES

An average of about 120 cords of unpeeled southern pine pulpwood is needed to produce 100 tons of newsprint (150). Approximately 170 cords are required for 100 tons of moisture-free sulphate pulp, and about 90 cords for 100 tons of moisture-free groundwood pulp. The highest yield of screened pulp comes from the middle sections of trees. (Some slow-growing trees are exceptions to this rule.) Screenings from butt logs are high, and top logs yield the least amount of pulp.

Springwood and Summerwood

Morphological differences in springwood and summerwood affect the bulk and surface characteristics of pulp sheets. The sharp contrast between springwood and summerwood and the frequent occurrence of compression wood make southern pine a tricky wood to grind. In chemical pulps, the springwood fibers, because of their thin flexible walls and large cavities, readily collapse into flat, ribbonlike shapes that produce a closely knit, well-formed, and smooth-surfaced sheet of paper. By contrast, the thick-walled, needlelike fibers of summerwood fail to collapse and hence yield a bulky and rough-surfaced sheet. As springwood content increases, the bursting and tensile strengths of the resulting lighter-colored pulps increase, and the resistance to tear decreases, whereas an increase in summerwood fibers brings an increase in tearing resistance.

Compression Wood

Compression wood, which is prevalent in butt sections and leaning trees, has abnormal chemical composition, physical properties, and pulping characteristics. It contains more lignin than does normal wood, its yields are lower, and the pulp is weaker and more difficult to bleach.

Resinous Wood and Heartwood

For a long time the relative abundance of resinous wood and heartwood in virgin southern pine discouraged the sulphite and groundwood pulp industry from expanding in the South. In recent years, however, it has been practicable to use in these processes the second-growth wood containing relatively lower amounts of heartwood and resin.

Old-growth longleaf is mostly heartwood, the sapwood band being rarely wider than 2 or 3 inches. Sapwood has from 1 to 3 percent resin compared with 7 to 24 percent for heartwood (376). Resin is concentrated toward the base of the tree—some butt logs averaging 15 percent resin content are from stumps with 25 percent resin.³¹

³¹Contrast these old-growth trees with 35- to 40-year-old second-growth from Escambia County, Fla. Classified by growth rates, the resin contents of butt logs from the latter were: rapid, 8.3 percent; medium, 3.8 percent; and slow, 4.8 percent. The top logs contained 5.2 percent resin (150).

Despite its considerable resin content, longleaf with a high specific gravity and relatively high yield of pulp per cord is well adapted to the manufacture of strong, durable, natural-color sulphate pulps and kraft papers.³² The sulphate process is capable of using a high percentage of heartwood, the mechanical groundwood a low percentage, and the sulphite process no heartwood at all (20). A minimum of dark-colored, blue-stained, or resinous wood is desirable for groundwood-sulphite newsprint. Some segregation of the raw wood is also desirable in the manufacture of newsprint from semibleached sulphate and groundwood pulps—all dark, resinous, stained, or otherwise unsuitable wood being diverted to a mill using the sulphate or other alkaline process (135). Heartwood not excessively dark can be used in the groundwood process (136).

Growth Rate and Pulp Quality

In comparing longleaf pines grown on old fields at three different stand densities in Escambia County, Fla., Bray and Paul (46) found specific gravity highest in wood

Table 10.—*Effect of stand density and growth rate on yield and character of wood of longleaf pines 35 years old (After Bray and Paul)*

Item	Unit	Thin stand growing rapidly	Medium density of medium growth	Thick stand growing slowly
Stand characteristics:				
Approximate number of trees per acre	Number	350	600	1,200
Range in d.b.h. on sample plots	Inches	4-14	3-10	2-9
Average in d.b.h. on sample plots	do.	8.0	6.4	4.4
Rate of growth in rings per inch	Number	5.5	7.0	12.8
Pulpwood yields:				
Yield of rough bolts (3" or larger) per acre	Cords	41.6	39.7	36.3
Sticks per cord from 18-foot butt section	Number	44	89	232
Solid wood content of a cord (by displacement)	Cubic feet	78.4	82.3	76.2
Weight of a cord, wood and bark, as received	Pounds	6,245	6,374	6,152
Weight of a cord peeled	do.	5,615	5,714	5,310
Weight of a cord peeled and oven dried	do.	2,910	2,920	2,890
Volume loss from peeling (based on disks)	Percent	13.0	9.0	14.4
Weight loss from peeling (based on logs)	do.	10.1	10.4	13.7
Wood characteristics:				
Specific gravity of oven-dry wood (green volume)	----	.548	.558	.590
Specific gravity of oven-dry wood (dry volume)	----	.606	.636	.678
Weight, oven-dry, per cubic foot green	Pounds	34.2	34.8	36.9
Weight of oven-dry chips per cu. ft. of air-dry volume	do.	16.4	16.3	17.7
Cellulose content	Percent	55.0	61.3	60.3
Lignin content	do.	30.9	29.8	31.8

³²In the sulphate process, the effective cooking chemicals are caustic soda and sodium sulphide, the former being more drastic in its action. Sodium sulphate and sodium carbonate, which unavoidably occur in the commercial liquors, are of no assistance in cooking (20).

of slow growth (Table 10). The yields of pulping material per cord, however, were about the same. Although the finished papers—wrapping, bond, writing, book, and glassine³³—showed some variations, they did not indicate any superiority in wood of one rate of growth over another. The ease of bleaching sulphate pulps was likewise independent of growth rate. From the standpoint of yield per acre, number of sticks per cord, efficiency in handling, and pulping and paper-making qualities, a stand of medium density, having medium and uniform rate of growth seems to be most profitable to operate (44).

SUMMARY

Longleaf pine wood is similar to that of the other southern pines, but can sometimes be distinguished in basal cross sections of stumps or timbers. Structural timbers of high quality and large size won an enviable reputation for old-growth longleaf pine. Longleaf timbers exported to England in the 19th century brought prices 25 percent higher than any other American pine. Nearly all trees were worked for turpentine before being cut. The species was widely used for lumber because of its abundance and quality.

Less than half the volume of old-growth longleaf trees was utilized until pulp mills began to convert the tops and limbs into paper. Now little of the second-growth tree need be discarded, but much of it is still not very profitably utilized. Chemical conversion of wood to produce such substances as sugar, alcohol, and plastics promises intensified future use. Conservative use of timber for sustained production of naval stores has been furthered by many research developments in methods of working. The most recent improvement is the chemical stimulation of turpentine faces.

Second-growth longleaf is used for naval stores, piles, poles, posts, ties, mine timbers, lumber, and pulpwood. Minor uses include cross arms, veneer, stave bolts, and blocks for other special purposes. Longleaf pine needles are used for pine oil, pine wool, poultry-house litter, and miscellaneous decorative purposes.

Seasoned lightwood produces naval stores in competition with similar products from living trees, and millions of tons of this material are still available in stumps and other remnants of virgin trees.

Lumber is still a major product of longleaf pine. Sawlogs less than 8 inches can seldom be manufactured profitably into lumber. Large mills can saw profitably only logs more than about 1 foot in diameter. Small trees removed in thinnings, and also small top logs, can be utilized best for pulp.

Stumpage prices for longleaf pine have shown an upward trend, increasing a hundredfold between 1883 and 1923. Following the peak production in 1909, output declined steadily, but increased again during World War II. Stumpage prices rose during the 1930's and early 1940's.

In 1920 the gum naval stores industry reached a peak in value of products. This industry migrated from the Carolinas to Texas just ahead of the timber cutters and is now stabilized in the second-growth forests of Georgia and Florida. Its continua-

³³For demonstrating that southern pine can be used for papers other than the kraft type, including white papers, much credit is due to the Forest Products Laboratory and the late Dr. Charles Herty of Savannah, Ga.

tion at present levels will depend on the extent to which improved efficiency enables it to compete with mineral substitutes and with wood naval stores.

Trees worked out for naval stores are available for wood products. With the possible exception of the turpented butt, their strength and pulping qualities are unimpaired.

The wood of longleaf pine tends to be weaker in the upper than in the lower portion of tree trunks. Position alone, however, is not a reliable indicator of strength. Contrary to popular belief, heartwood is not necessarily stronger than sapwood; strength and width of rings are not closely related; and young or second-growth wood may be as strong as old or virgin growth. Strength depends mostly on density, moisture content, and freedom from defects.

Density of yellow pine, as shown by the percentage of summerwood, is closely related to weight and strength. Among the southern pines, longleaf has the heaviest and least variable summerwood, also the most distinct seasonal banding within the annual rings. While these characteristics somewhat lower the workability of the wood, they increase its strength. As in other southern yellow pines, compression wood, undesirable in both lumber and pulpwood, is formed in leaning longleaf trees. When free from compression wood and other defects, the mechanical properties of clear wood of a given moisture content are closely related to its specific gravity.

Moisture content and defects, as well as specific gravity, affect the strength of wood. All sound and clear wood increases in strength as it dries. Below the fiber-saturation point, the logarithms of strength values increase directly with decreases in moisture content. The tendency to gain strength in seasoning may be seriously offset, however, by simultaneous development of defects in larger pieces, and by the presence of knots. Large timbers are roughly only two-thirds or three-fourths as strong as small samples of clear wood.

Durability is likewise affected by moisture, which is vital to decay organisms. They cannot grow without it. Neither dry nor saturated wood decays. In pine the resin content also may retard or prevent decomposition. Sapwood is highly perishable, while heartwood is moderately long lasting, and if resinous, is extremely resistant to decay. Heartwood is not penetrated by preservatives as easily as sapwood, but has less need of such treatment.

The suitability of wood for pulp depends on various elements. Longleaf wood fibers are rather long, and in summerwood their cell walls are relatively thick and dense, making this darker wood more suitable for coarse papers. Compression wood, rare in well-managed stands, reduces yields, weakens pulp, and makes paper difficult to bleach. Except for kraft paper products, wood containing little or no heartwood or other highly resinous wood is desired by pulp mills. Fortunately, longleaf under 20 years of age is free from heartwood, and later has less of it in rapidly grown second growth than in typical old growth. All in all, stands of moderate density and medium rates of growth are the most satisfactory sources of many forest products, including pulpwood.

Part 2. ECOLOGY



Figure 11.—Range of longleaf pine and the forest types in which it predominates. Types are differentiated in Figure 1. (Southern Forest Survey data.)

III. Natural Distribution

ORIGINALLY the pine forest of the longleaf belt was unbroken over extensive areas except for the moist bottom-land sites. The present longleaf forest occupies probably only one-third to one-half the original area.

As early as 1883, it was reported that longleaf stands often failed to reproduce themselves after logging and usually gave way to slash pine along the coast in the Southeast, and to loblolly and hardwoods further north and west (314, 572). In 1888, Mohr (396), a keen observer, concluded that the prospect of maintaining a longleaf forest seemed hopeless. Similar conclusions were voiced forty or fifty years ago by various students in different States throughout the longleaf belt (12, 157, 172, 603). The area in longleaf pine has receded far and in many places pure forests have been succeeded by mixed pine and hardwoods.¹

Continued recession has been due to ecological disturbances, aggravated by overcutting. Among these are changes in the frequency of burning, the grazing of numerous hogs, and seedling disease.² On the whole, however, it is generally agreed that the longleaf pine type is not a climax in the sense accepted by ecologists (i.e., a community in essentially stable adjustment with soil and climate), but rather a fire subclimax (102, 604), that is, a successional stage that owes its long-time occupancy of extensive areas to the occurrence of frequent fires.

BOTANICAL AND COMMERCIAL RANGE

The natural range of longleaf pine is controlled principally by the limitations of latitude, altitude, and physiographic subregions. It is modified locally by certain characteristics of sites and soils. Within these natural limits, the areas occupied are further affected by the impact of civilization with its accompaniment of logging, hog damage, and fire. The net effect is a change in forest type so pronounced that its nature can be appreciated only through a review of the factors which control the distribution of the species.

In 1915 it was estimated (72) that the longleaf pine belt covered more than 100,000 square miles, from the southern part of Virginia to central Florida and from the westernmost flatwoods of the Gulf Coastal Plain in Texas to the foothills of the Appalachians in northern Alabama and Georgia. The main belt was 100 to 200 miles wide, averaging 125 miles and seldom extending over 150 miles from the coast (Fig. 11). Progressing inland, longleaf was found in three main physiographic divisions: (1) the Coastal Plain, (2) the pine barrens, and (3) the mixed-pine up-

¹Evidence is found throughout the territory where longleaf stumps are present in the mixed pine-hardwood forest. A few exceptions, however, have been noted. For example, loblolly did not encroach upon longleaf to any marked extent in Berkeley County, S. C., according to C. S. Chapman (90), nor in Baldwin County, Ala., nor in parts of Georgia. In Louisiana and Mississippi there are places where the cut-over lands have escaped a change of species, but new growth of longleaf is generally sparse or absent.

²The clearing of land for agriculture has also had profound effects on the ecological succession of insect and animal populations which reacted on the forest itself. The indirect but striking changes in the forest, induced by the combined action of all these causes, will be made clear in later chapters.

lands. The original boundaries of the longleaf belt were remarkably distinct, the transition zone to other types of forest often being less than a mile wide (169).

In general, the finest stands on small tracts were found in the hilly interior, while the densest stands over extensive areas were near the Gulf Coast, especially in Louisiana and Texas. On inland areas in Alabama and Louisiana the species occupied poor soils. In the uplands, longleaf was found only on the ridges, but here the trees were larger and more numerous per acre than on lower sites.

In the present century the botanical range has changed little, if any, while the commercial range has receded in many places. Somewhere between the botanical and present commercial limits lay the original boundaries of the longleaf pine forest type. In general, the gross area of this forest type is much smaller than formerly. Because the net area originally occupied exclusively by longleaf is unknown, the immense acreage denuded or relinquished to other species cannot be measured. Figure 11 does not reveal the flatwood areas in the Southeast that are thickly pock-marked with small ponds supporting other types of forest. Nor does it show how in more rolling terrain the longleaf stands are interrupted by innumerable narrow belts of hardwoods along the minor streams and drainage lines. The northern boundary has receded and the longleaf type in many places has been moving away from the moist borders of ponds and stream bottoms.

Scattered individuals or small groups of longleaf pine trees are found outside the main body of the type, as, for instance, in Brunswick County, Va., and a few outposts have been discovered even beyond the northern limits mapped in 1897.³

STAND ASSOCIATES

Original stands of longleaf were generally pure only in respect to dominant tree species.⁴ Purity seldom persisted undiminished in second growth; nor did it ever include minor arborescent vegetation. Tolerant of both fire and shade, the flowering dogwood (*Cornus florida*) and several species of oak with scrubby growth habits are common understory associates.

In many places much of the understory takes a new and menacing lease on life following the cutting of timber (Pl. 11). Where promiscuous burning in the original forests was continued after partial cutting, there were usually too few hardwood trees to be of silvicultural concern, although where sparse ground cover reduced the intensity of frequent fires, some hardwoods flourished. Under other conditions, wild fires often failed to hold back scrub oaks after full release by clear-cutting and destruction of pine. In this way scrub oaks in many instances completely captured longleaf sites, as in western Florida. This sequence was not universal, however.⁵

³Undoubtedly these represent omissions in the early records rather than any subsequent advance on the ground. Munson (401) mentioned the occurrence of the species in Liberty and San Jacinto Counties, Tex., in 1883, although its present western limit is in Trinity and Polk Counties. Isolated bodies of longleaf were reported by Harper in 1923 north of the recorded limits in Alabama and Mississippi, and others were recently observed in the same vicinity, near the southeastern corner of Neshoba County, Miss.

⁴Stands are generally considered to be pure if at least 75 percent of the dominant trees are of a single species. Longleaf forests are often 100 percent pure.

⁵Sherrard (497) noted in 1903 that in Hampton and Beaufort Counties, S. C., scrub oak rarely followed the removal of pine, as it did in many other parts of the South.

Regional Cover Types

Three cover types containing longleaf have been recognized by the Society of American Foresters: longleaf pine, longleaf pine-turkey oak, and longleaf pine-slash pine.

In the longleaf pine type the common associates on dry sites are blackjack oak, (*Quercus marilandica*), bluejack oak (*Q. cinerea*), and dwarf oak (*Q. stellata margaretta*), or on limited sandy areas, turkey oak (*Q. laevis*). On moist sites the common associates are slash pine, sweetgum (*Liquidambar styraciflua*), southern red oak (*Q. falcata*), and loblolly pine. The longleaf pine type is regarded as a subclimax naturally succeeded by other types. Cutting accelerates this succession.

In the longleaf pine-turkey oak type the common associates are turkey oak and bluejack oak. On dry sands, saw palmetto (*Serenoa repens*) is common, and on the driest sites, sand pine (*Pinus clausa*) often occurs. This type of forest often replaces longleaf after heavy cutting and repeated fires.

The longleaf pine-slash pine type is composed mainly of longleaf and slash pines, sometimes with a small mixture of water oak (*Quercus nigra*), laurel oak (*Q. laurifolia*), and other oaks. On ground intermittently wet, loblolly pine and hardwoods such as blackgum (*Nyssa sylvatica*) are frequent associates. On many areas this type of forest has succeeded pure longleaf mainly because hogs have destroyed much longleaf reproduction, and fire protection has favored encroachment by slash pine.

To obtain a clearer picture of the original forest, two descriptions of virgin longleaf in 1905 may be examined (90, 464). At that time large parts of Berkeley County, S. C., were covered with longleaf stands, pure except for a scattering of loblolly and a lower story of hardwoods. Where soil moisture was adequate, loblolly was more plentiful. Where the soil was very dry, oak sprouts sometimes occupied small areas to the exclusion of pine. A survey of all trees one inch in diameter and larger on frequently burned upland pine tracts in Coosa and Bibb Counties, Ala., showed that the forest was 80 to 86 percent longleaf. Originally these areas were relatively free from hardwoods. Considering only trees 10 inches in diameter and larger, the stands were 84 to 94 percent pure longleaf, with varying amounts of loblolly and shortleaf. By contrast, adjacent, rarely burned-over creek lands supported much less longleaf—6 to 28 percent of all pines 1 inch and larger in diameter, or 3 to 14 percent of all trees, including hardwoods. On these moister sites the hardwoods were white and black oaks, sweetgum, yellowpoplar (*Liriodendron tulipifera*), and others, constituting 56 to 60 percent of the merchantable stand.

Minor Herbaceous Vegetation

The longleaf pine type of forest possesses rich herbaceous communities. For instance, a botanical exploration (504) in the longleaf pine-turkey oak type of forest of the Bellair sand region south of Tallahassee, Fla., revealed about 250 species of herbaceous plants.

Normally, longleaf is associated with various grasses, locally called wire grass. Most of them form bunches rather than turf; many are coarse and inferior as

forage. Species of *Andropogon* often predominate in the western portion of the longleaf belt, and *Aristida* in the east. In the Southeast, minor vegetation, such as saw palmetto, often develops dense masses of roots that inhibit the establishment of pine seedlings (Pl. 12).

In North Carolina, pineland three-awn (*Aristida stricta*) is coextensive with longleaf pine over a wide range of sandy and loamy soils (604). In Louisiana and Mississippi little bluestem (*Andropogon scoparius*), slender bluestem (*A. tener*), or both, commonly dominate the grasses of better-drained longleaf sites. *Andropogon virginicus*, usually called broomsedge, is more prominent on the moister portions where longleaf is being succeeded by other tree species. Any grass associated with longleaf must, of course, be inured to fire, but *A. tener* is somewhat more fire-hardy than its coarser associate, *A. scoparius*. Of special interest is carpetgrass (*Axonopus compressus*), an exotic plant of prostrate growth habit, valuable as forage. Only on unoccupied spots or on grazed areas can this plant spread naturally in competition with native grasses (587).

The ground cover formed by grasses is naturally heaviest in the moister and more open areas. The soil is only half as well covered in second-growth as in virgin longleaf stands, while on cut-over areas grass cover is about twice as heavy (433).⁶

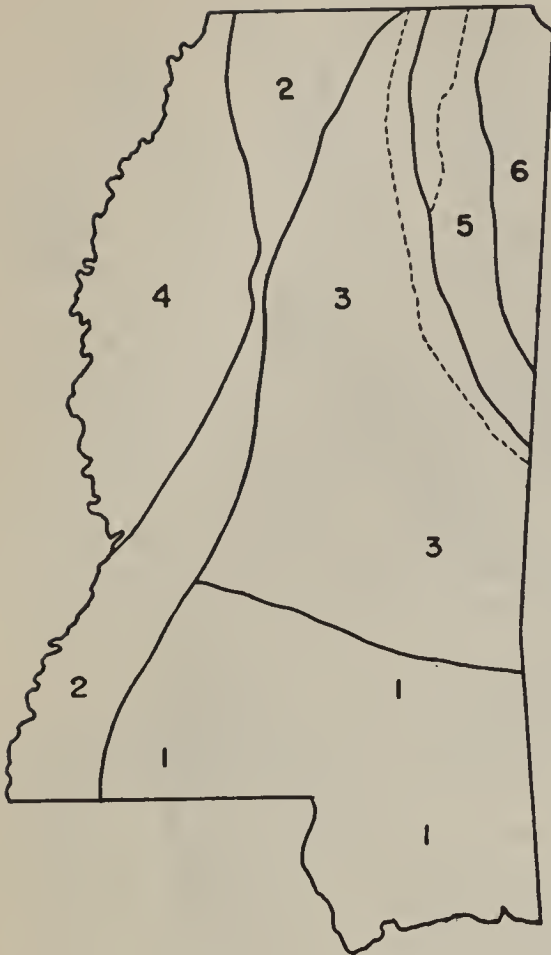
GEOLOGIC FORMATIONS

According to Sargent (481, p. 537) the original pine forests coincided almost exactly with certain geological formations. Along the northern edge of its range longleaf is said to have been used as an indicator of underlying geological strata. For example, from Trinity County to southeastern Sabine County, Tex., the species follows the coarse sandy zones of the Catahoula formation and the upper sandy zones of the Jackson or Fayette formations. It nearly coincides with the Fayette Prairie formation east of the Trinity River (185). In Louisiana longleaf is present on nearly all the Catahoula formation but is less consistently related to other formations, such as the Cockfield, a division of the Claiborne. In central Texas longleaf seems to have been most abundant on the older Pleistocene terraces. It appears to be uniformly present on the Miocene (Catahoula) formation, irregular on other Tertiary materials, and absent from the Wilcox. In southern Louisiana, as in western Vernon Parish, longleaf grows on the sandy phase of the Prairie terrace but is absent from the clay phase.⁷

Figures 12 and 13 show the extensive longleaf pine belts in Mississippi and Alabama.

⁶Because the competitive menace and significance of most herbaceous plants has not been precisely measured, plant inventories thus far reported are of limited value. Existing knowledge of conditions in virgin longleaf forests has come in large part from the keen observation of Roland Harper. For example, in 1914 he published a list of trees, shrubs, woody vines, and herbs for Mississippi (247). This was supplemented by the more intensive studies of Lowe (358) in 1921. In 1912 and 1913, Harper published lists of plants found in the longleaf pine sections of Georgia and Alabama (243), supplementing the thorough earlier work of Charles Mohr (398). Other botanists who have made similar studies in Louisiana and Florida are Gano (191), Penfound (433), Uphof (570), and Pessin (445). See Appendix II for lists of plants in longleaf types.

⁷Prof. Clair A. Brown, Louisiana State University, in a letter to the author, Feb. 13, 1942.



MISSISSIPPI

1. LONGLEAF PINE REGION
2. YELLOW LOAM REGION
3. RED HILLS
4. DELTA
5. BLACK PRAIRIES
6. NORTHEASTERN HILLS

Figure 12. — Physiographic regions of Mississippi, showing extensive longleaf pine region. (After R. M. Harper)

At high elevations in central Alabama, longleaf inhabits the Paleozoic rocky soils formed from siliceous slates and quartzites. The highest ridges in the Coastal Plain, frequently capped with sands and gravels of the Lafayette formation or with soils formed from Buhrstone strata, are covered with longleaf (398, p. 107). The species also tends to predominate wherever the older rocks are deeply hidden under sands and gravels; where the soils are more fertile and derived from gneissic rocks and clayey slates, longleaf is generally replaced by shortleaf and loblolly.⁸ On the whole, geologic formations are not sufficiently homogeneous to determine the forest type without reference to site and soils.

Like the virgin timber which it succeeded, second-growth longleaf is naturally most prevalent in the southern portion of the Gulf Coast States.⁹

SITES AND SOILS

Forest productivity in any locality is determined mainly by site factors which are classified as climatic, edaphic, or biotic. In the case of longleaf other factors, such as fire and the widespread destruction of the original forests by man, are also of importance.

Climate

Precipitation and temperature are the noteworthy climatic influences that affect the distribution of longleaf.

Where snowstorms are heavy, longleaf is distinctly out of its element, since its branches cannot support heavy loads of wet

⁸Pessin, L. J. Ecological aspects of the longleaf pine type. 1940. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

⁹In 1900 longleaf was reported, perhaps erroneously, as abundant on Ship, Cat, and other sandy islands off the coast of Louisiana and Mississippi, but not on black muck or very wet soils (350). Unmistakable original growth of longleaf pine has been noted, however, on Dauphin Island, Ala., in spots slightly drier than the surrounding slash pine forest land.



Figure 13.—Distribution of virgin longleaf pine stands in Alabama, 1912. Dots indicate relative abundance of stands, and solid lines represent boundaries of physiographic regions. (After R. M. Harper)

snow held by its long needles. This difficulty, however, is seldom encountered within its natural range.

Longleaf thrives where there is heavy summer rainfall to offset large losses of moisture caused by rapid percolation through and evaporation from sandy soils, and by transpiration during an exceedingly long growing season (612). In the longleaf pine belt annual precipitation, ranging from approximately 46 to 65 inches, leaches

Table 11.—*Climatic variations in the longleaf pine belt* (After Pessin)

Portion of range	Average temperature			Average precipitation		
	Mean annual	Maximum	Minimum	Mean annual	Maximum	Minimum
	° F.	° F.	° F.	Inches	Inches	Inches
Northern	63	106	—10	50	80	32
Southern	73	101	18	57	64	40
Western	67	108	7	46	57	31
Optimum	67	103	18	65	89	42

much of the available nutriment from sandy soils, yet favors well-developed pine forests. Table 11 shows variations in climate in the longleaf pine belt.

At the northern limits of the longleaf range in North Carolina and Alabama, for example, the minimum temperature recorded in Table 11, -10° F., and the maximum, 106° F., are rarely encountered. Wherever longleaf grows, the temperature commonly remains below 100° F., with a mean annual range of 63° to 73° F. Longleaf grows in warm and humid climates, but variations in this climate play only a minor role in the distribution of the species.¹⁰

Soil Moisture

The controlling effects of topography, drainage, and soil moisture on the distribution of longleaf pine are generally secondary to those of cutting, hog damage, and fire. Single factors, however, determine the presence or absence of longleaf under certain conditions. Where frequent woods fires have been widespread, the species sometimes occupies both wet and dry soils. For instance, the dry sand hills, the moister Norfolk soils, and the poorly drained Leon soils of the Southeast all support longleaf. By and large, however, the species occupies the better-drained and drier soils. Indeed, except for the narrow live-oak belt along the coast, longleaf was originally the characteristic tree of all well-drained soils on both the Atlantic and Gulf Coastal Plains. Figure 14 shows the physiographic distribution of longleaf pine in relation to other tree species.

The longleaf pine belt is divided as follows: Lower Coastal Plain, 31 percent (well-drained sandy areas, 11 percent, and poorly drained flatwoods, 20 percent); and Upper Coastal Plain, consisting of well-drained sandy loams or fine sandy loams, 69 percent.

In competition with other species, longleaf pine occupies very dry sites apparently from necessity rather than preference (48), as shown by thrifty specimens planted or accidentally seeded in widely different situations (243). Under competition for space, longleaf is found avoiding the wet limestone sinks and damp borders of ponds in the flatwoods and even the moist margins of intermittent streams and drainage lines in the rolling country, where it takes full possession of the ridges.

Throughout its range, exclusion from certain sites can be explained by drainage. Longleaf is more sensitive to flooding in the seedling than in the later stages. A regenerating forest has been observed to advance toward moister sites during a series of dry years, only to retreat during wet years (123). Larger trees, however, are not

¹⁰In Alabama, longleaf is found on sites which, because of elevation, are as severe as if they were located several hundred miles north of its natural range. Thus, on the Talladega National Forest in northern Alabama, longleaf grows at nearly 2,000 feet above sea level (251).

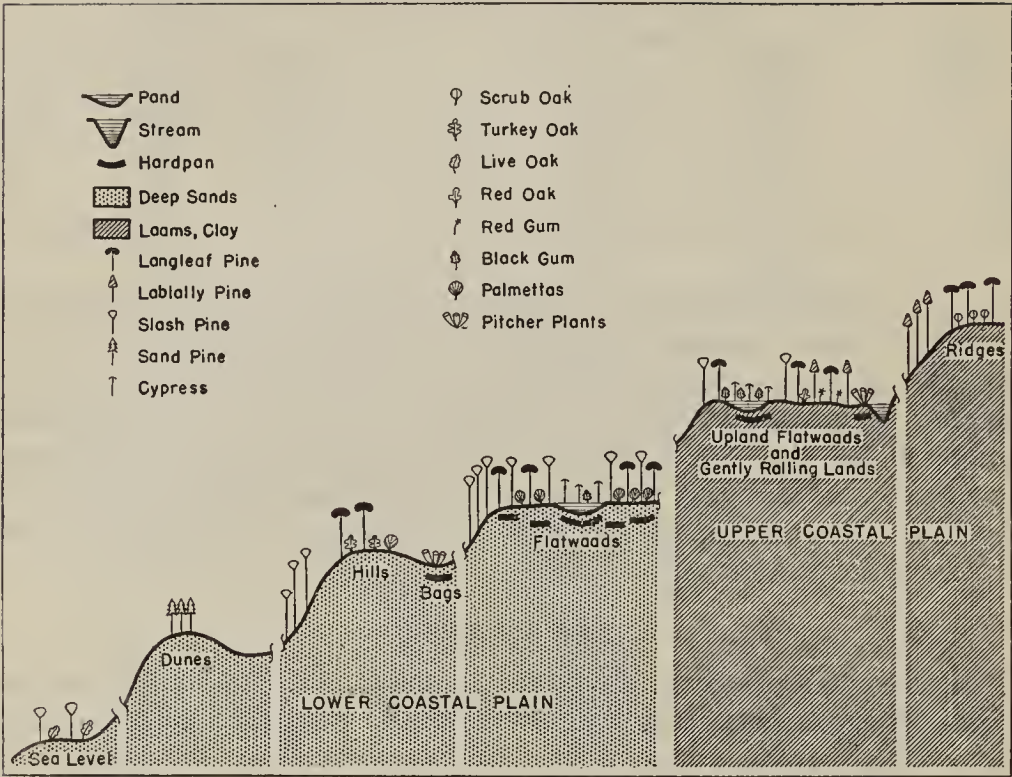


Figure 14.—Generalized profile of forest communities in the longleaf pine belt, showing a cross section from sea level through the Upper Coastal Plain. The vertical scale is greatly exaggerated to show topographic relationships, and the natural sequence of forest communities is simplified. (After Pessin)

killed by occasional flooding. Furthermore, they withstand the dearth of oxygen or acidity of swamp water better than do some dry-land plants. In other words, longleaf tolerates boggy soils as well as dry sands, and this enables the species to persist over a wide range of habitats (603).

In considering the effect of drainage on the distribution of longleaf, the origin of the numerous small treeless areas (savannas) in depressions bordering drainage lines must be noted. Such areas are now too wet for the reproduction, if not also the growth of the species, yet longleaf stumps on some savannas suggest that in the past these areas were less completely saturated with water. Increased precipitation may have raised ground-water levels, but the harvest of the virgin timber could have induced such a change since large trees consume great quantities of moisture. The removal of trees on adjacent higher ground may have increased the lateral drainage or run-off into the savannas, while the clearing of the areas themselves cut off the upward drainage through transpiration. Thus the cutting of the forest may have produced saturated soil in depressions and prevented the reestablishment of longleaf.

Soil Fertility

Longleaf grows on soils that are siliceous rather than calcareous, and relatively low in fertility (172). Within these broad limits, however, the species obviously

tolerates a wide variety of soil conditions. On the peninsula of Florida, for example, the rolling pine lands are typically light sands and sandy loams of varying textures, at least at the surface. Some are quite pervious, but others have heavy subsoils that roots can penetrate only with difficulty. In the Alabama Piedmont, longleaf subsoils are mostly coarser or heavier loams that contain clay, slate, or gravel, but the surface is generally sandy. The best development of timber is invariably found where the subsoil contains considerable clay but is porous enough to allow easy percolation.

As compared with other regions, the organic layers of soil in the longleaf belt are low in nitrogen and calcium (287).¹¹ The species is generally absent from some of the extremely poor mineral soils within its range, such as the white sand of the "Florida scrub" and dunes along the Atlantic coast. Although longleaf soils are characteristically poor in organic matter, acid in reaction, and low in fertility, the response of the species at any age to soil enrichment is strong evidence that poor soil is not preferred. Research evidence indicates that arid and infertile habitats are endured from necessity, not choice.¹²

Longleaf has grown slowly and remained short but has produced fine timber on the deep sterile Norfolk sands of the former Choctawhatchee National Forest, Fla.¹³ Other soils of the Norfolk series are more productive. The following tabulation shows the relative frequency with which certain soils support stands of longleaf in 67 representative counties throughout the range of the species:

<i>Soils</i>	<i>Percent</i>	<i>Soils</i>	<i>Percent</i>
Coastal Plain:		Coastal Plain (<i>continued</i>):	
Norfolk	87	Greenville	13
Orangeburg	60		
Ruston	55	Flatwoods:	
Kalmia	45	Plummer	33
Susquehanna	40	Portsmouth	28
Cahaba	30	Leon	18
Myatt and Leaf	27	Coxville	15
Tifton	19	Scranton	13
Caddo	18	St. Johns	10

The Norfolk series is first, followed by the widely prevalent Orangeburg and Ruston soils. These data are representative of the longleaf pine belt but cannot be used to deduce any preference of the species for certain soils. Usually excluded from the better soils by competition with less fire-hardy species, longleaf has become thoroughly inured to many relatively unfavorable growing conditions within its wide natural range.

In southern Alabama and elsewhere the species reproduces itself naturally and grows excellently on well-drained rolling uplands. Here regeneration is not impeded by the palmetto so prevalent on the coastal flatwoods (Pl. 12). Land well suited to

¹¹Brief descriptions of many of these soils are given by Bennett (27). Detailed descriptions are found in the soil survey reports of the U. S. Bureau of Soils for various counties and districts.

¹²For instance, use of compost of virgin topsoil to improve the physical nature and fertility of nursery soils induces superior development in seedlings. Likewise, older trees occupying an extremely sterile soil responded in thrift when fertilized and watered. A nitrogen-phosphorus mixture and irrigation during the dry season increased the growth period and length of needles on mature pines. In this particular experiment excessive moisture was precluded by a naturally rapid percolation rate.

¹³The forest was transferred to the War Department in 1940. It is now the Eglin Field Military Reservation.

longleaf, however, is not confined to the uplands. The pure type on land too flat to erode is found mainly in southern Georgia and northern Florida.

Tolerance of sterile soil fits in with the apparent resistance of longleaf pine generally to adverse site conditions. Ness (407) found that the species was well adapted to the soil at College Station, Tex., regarded as unfavorable to most forest trees. However, by artificially introducing longleaf on soils to which it was not accustomed, he evolved what now appears an oversimplified theory of natural distribution, namely, that longleaf pine inhabits only sandy and clayey loams very poor in organic matter "not because this is a necessity for its growth, but because its seedlings perish from damping-off during early infancy if germination takes place on soil containing a perceptible amount of humus" (408). Disease organisms in the soil are certainly an edaphic factor to be reckoned with, but to complete the picture of what happens to seedlings during their critical stage, it is essential that unfavorable factors operating above the soil also be considered.

In its natural range, longleaf grows on poor as well as on good soils because it can withstand fire and unfavorable ecological conditions better than can its arborescent competitors. Productivity of longleaf is often greatest on moist sites outside of its typical habitat. Normally, from 4½ to 13 years are required for seedlings to reach breast height. Unhealthy conditions may lengthen the period, but in their absence any departure from the average is traceable to site quality. For example, seedlings 2 feet high by the third year have been found on moist loose soils (other than coarse sands) well supplied with subsoil moisture (16).

Beyond the seedling stage, the productivity of any site must be judged by the growth in height or diameter of dominant trees which had unobstructed growing space. Variation in soils sometimes can be judged from the number of rings in the last radial inch of wood and more often from site index, or the height of dominant trees at 50 years. Thus at a point near Olustee, Fla., the growth of longleaf pine trees on Leon soil was 7.2 rings per inch and 62.8 feet in height as compared with 5.5 rings and 75.5 feet, respectively, on Norfolk soil. In southern Georgia, longleaf pine averages only 66 feet in height at 50 years of age (338), whereas on the heavier soils of southwestern Louisiana it attains 20 or more feet of additional height at the same age.

BIOTIC AND HUMAN INFLUENCES

Fire and soil moisture have largely determined the local occurrence of longleaf pine, but the natural distribution has also been modified by destructive agents such as certain fungi, insects, and birds. The principal impact of civilization on longleaf has come through destruction of the forests by men and range hogs. The latter, seeking edible bark, have killed seedlings, while steam skidders have taken the larger trees, leaving considerable land denuded.

The pattern of the longleaf forest, formed largely through the action of fire burning over the drier soils, might have been changed still more profoundly if there had been a greater demand for the agricultural use of longleaf sites. Actually agriculture has claimed a relatively small portion of such sites compared with moister and more fertile localities. Since the less desirable longleaf soils were generally

avoided by farmers, the absence of extensive agricultural encroachment on virgin forest roughly indicates where much of the true longleaf soil lies. Soils not fit for agriculture, however, are not necessarily unfavorable to longleaf. Considerable areas not suitable for tillage are available for the production of this species (179).¹⁴

Clearing the original forest for lumbering or farm use has greatly restricted the area in longleaf without radically changing its characteristic pattern of distribution. Thus the original expanse of forest has been interrupted by scattered fields and many roads, but in general fire and soil moisture continue to delimit unmolested second growth as they did virgin growth. Abandoned old fields usually restock with other tree species if seed is available, but some are reclaimed by longleaf.

SUMMARY

In the natural succession of forest types longleaf pine forms a subclimax maintained through frequent burning of the forest floor. Fire furnishes the primary control of distribution of longleaf pine under natural conditions, but its action is largely felt through effects on competing forest species.

The over-all limitations of climate play a negligible part in the local occurrence of the longleaf type. On most of the low ridge sites the high seasonal loss of soil moisture through percolation, evaporation, and transpiration is largely offset by the heavy summer rainfall.

Soil moisture ranks next to fire in determining the distribution of longleaf. Like fire, its most significant effects are indirect. On low-lying flatwood areas, longleaf seedlings often succumb if subjected to inundation, but larger trees can stand the occasional flooding and saturation of poorly drained sites. Young trees also tolerate the physical restrictions of hardpan layers. The best ultimate development of longleaf, however, is attained on those superficially sandy soils that have a heavy but not impervious subsoil.

When competing with other trees, longleaf occupies the drier, less fertile, and more frequently burned sites from necessity rather than preference. It maintains itself against competition more readily in the drier situations than on moister sites, where its growth may be more rapid. Relatively moist situations can be held by longleaf only when not cut over, and with the aid of fire.

Fertility, like climate, plays a role subordinate to fire and moisture. The species is not discriminating as to soil fertility, but is usually excluded from the better soils by the aggressive seeding, sprouting, and growth of less fire-hardy competitive species. Following heavy pine cuttings, many of the poorer soils are captured by

¹⁴Forbes wrote that "some of the longleaf pine hills have very abrupt slopes, especially where the breakoffs into the main stream occur, and these are nonagricultural. Again, certain areas of peculiar distribution, but of fair size, have deep sandy soils, underlaid only at depths of 18 inches to several feet by an impervious subsoil. Here a condition of physiological aridity so far as ordinary shallow-rooting crops go, is in nowise a bar to fair growth by the deep-rooted longleaf pine. . . . The nonagricultural lands scattered through the cultivated portions of the longleaf pine region are in far larger units than in the shortleaf" (179, pp. 507-508). One such unit has remarkably uniform soil conditions: 53 percent Ruston and 33 percent Orangeburg fine sandy loams.

Elsewhere some other soil may happen to support most of the longleaf pine. For example, Chapman (101) reports that in Baldwin County, Ala., a large timber company was buying only lands already heavily stocked with second-growth longleaf pine of sapling and pole sizes, and these were found to coincide closely with the Norfolk series of soils.

commercially inferior species, such as scrub oaks. Longleaf develops slowly but thriftily on poor, sandy soils, where all other commercially important native tree species languish. Richer soils may induce more rapid growth and greater height at maturity, but usually no greater ultimate quality.

Although longleaf occupies extensive areas of submarginal agricultural land, it is common also on marginal or semiagricultural soils, such as Norfolk, Orangeburg, and Ruston sandy loams. The various longleaf pine soils are relatively poor in organic matter, calcium, and nitrogen. On the poorest soils the growth of any tree species is relatively slow, although much second-growth longleaf is producing at a rate that is remarkable on poor soil. Longleaf grows well and makes a highly satisfactory timber tree on soils too poor and dry for other commercial southern pines.

The impact of civilization on the primeval forest has been felt in the following ways: (1) old growth was destroyed by cutting and steam skidding; (2) seedlings have been killed by range hogs, disease, or vegetative competition; (3) new growth has been exploited for turpentine and other products; and (4) changes in burning frequency have restricted longleaf reproduction. The nature of these changes is discussed in the following chapters.

Longleaf excels other pines in its tolerance of adverse conditions such as severe burning and abusive handling. Clear cutting and unfavorable changes in the frequency of burning have made heavy inroads on the longleaf type in most places, but have left scattered remnants. Civilization has greatly reduced the original forest without reshaping to any great extent the over-all character of its natural distribution.

IV. Role of Fire in Regeneration of Longleaf Pine

LONGLEAF PINE is a temporary type in that without the influences of fire and man it would eventually be succeeded by a forest of mixed hardwoods. Any management system, therefore, that maintains longleaf as a forest must arrest the trend of natural succession. Among the natural factors controlling the regeneration of longleaf, fire is undoubtedly most influential.

Lightning¹ must have been the principal cause of fires in the piney woods before the Indians came to the American continent. Subsequently, both Indians and white settlers engaged in frequent woods burning. Before settlement, the longleaf pine forests were burned irregularly, perhaps at intervals averaging once every 2 or 3 years (252). Occasional severe fires in spring or summer prepared the ground for extensive regeneration of longleaf. Striking when the resistance of vegetation is at its lowest, these fires destroyed or reduced the less fire-hardy plants in the forest, while longleaf seedlings, starting on ground thoroughly cleared of combustible material, had a good chance of coming through their own highly vulnerable stage to form a fire-resistant stand. Succeeding fires kept down competing vegetation, thus maintaining the original stands of longleaf pure in composition and open in character.

Opinions differ as to the effect of settlement on the frequency of fire. With the human source of ignition rapidly increasing, burning may have become more frequent but less severe in some places. On the other hand, the clearing of fields and extension of roads by settlers restricted the spread of fire to an extent that may have offset the effect of increased ignition.

After settlement, probably 90 percent of the longleaf forest burned over at least once every 3 or 4 years, on the average. So far as is known, every area of significant size occupied by longleaf bears evidence of past fires.

Fires in the piney woods are usually of the surface variety, with flames seldom exceeding 6 feet in height. Creeping fires are frequently halted by fallen logs, damp depressions, and roads. Subsequent fires, however, may approach an area from a different direction, and, feeding on a greater accumulation of debris in unburned spots, leave different patches of the forest unburned. This local immunity from fires on unprotected areas, therefore, is usually temporary, not lasting long enough to permit the establishment of other species. As a rule, surface fires consume or char the forest litter and kill to the ground low vegetative cover other than longleaf.

The original unexploited longleaf forest was self-perpetuating, but the white man found that it reproduced itself only where openings in the overwood permitted young stands to develop. The result was a parklike, uneven-aged forest, characterized by scattered even-aged stands of trees in large areas between streams. Many of these stands were in the flatwoods of the Lower Coastal Plain. Further inland, the longleaf pine forest followed the multiple ramifications of minor ridges, leaving the

¹Although on the average 10 lightning strokes a year have been reported for every square mile in the United States, relatively few start fires. Most fires so started are extinguished by rain.

lower sites—those too moist to burn over often—to hardwood trees. These hardwoods were usually mixed with slash pine in the southeast portion, and with loblolly pine and sometimes with shortleaf pine in the northern and western portions of the longleaf belt. Thus, the pure longleaf virgin forest covered extensive areas on the drier and frequently burned uplands.

ROLE OF FIRE IN SEEDLING ESTABLISHMENT

In its juvenile or "grass" stage longleaf pine possesses certain adaptations, such as a low habit of growth, stout taproot, and thick bark, that make it resistant to fire. The hottest flames from grass fires often pass above the seedlings. Since the roots are large in relation to the tops, there is usually ample stored food for the replacement of needles lost in periodic fires. Vigorous seedlings fail to make prompt restoration of foliage only when burned or otherwise defoliated annually. Annual fires are much more debilitating to the seedlings than fires coming at longer intervals because second-season foliage is consumed or heat-killed before an emergency food supply is produced. The thick outer bark protects the cambium from lethal temperatures.

In their cotyledon stage, however, longleaf seedlings are highly vulnerable to fire, being killed outright by flames. Even in the grass stage the weaker individuals gradually succumb to repeated defoliation. In the larger seedling and sapling stages, longleaf excels all other southern pines in fire resistance.²

The good and bad effects of burning, as well as of exclusion of fire, must be carefully considered by forest managers, since a given treatment can either assure or preclude the continued predominance of longleaf as a forest type. Indifferent handling of the species has already contributed to its widespread recession.

Second-growth stands have benefited from the presence of fire before seeding and from its exclusion afterward. As Chapman (103) pointed out, "practically all existing stands of second-growth longleaf pine which have survived the juvenile stage and have assumed a vigorous height growth and become saplings have originated on land which previous to the fall of seed has not been under fire protection." There can be little doubt that these sites were kept relatively clear of competing vegetation and brown-spot needle disease, and hence were receptive to successful reseeding following harvest through the combined effects of (1) complete occupancy by large undiseased trees and (2) frequent burning of the litter and ground cover. After vigorous growth begins, well-stocked stands of seedlings come through regardless of burning treatments. Subsequent fires may help to keep down competing vegetation.³

The main requirements of seed and seedlings in the process of natural regeneration are freedom from (1) barriers that prevent seeds from reaching mineral soil, (2) destruction by birds and hogs or other animals, (3) annual defoliation by fire or

²The resistance of any tree increases with diameter, bark thickness, and elevation of crown. Once out of the grass, longleaf acquires these advantageous characteristics relatively early in life. According to Harper (242), the length of needle should be included in the list of characters positively correlated with high resistance to fire, but no careful studies have been made to check or refute his theory.

³Some seedling reactions to fire appear inconsistent from casual observation. Fire may injure some seedlings by defoliation, but aid others through its sanitary and weeding effects. Similarly, the exclusion of fire injures some seedlings by burying them under grass or debris, but helps others to emerge.

brown-spot needle disease, (4) smothering by dead grass, pine straw, or other debris, (5) encroachment by aggressive underbrush, and (6) suppression by seed trees or an overstory of any kind. Fire affects all but the last item. Seedlings not subjected to these adverse conditions are thrifty and able to withstand complete defoliation from an occasional fire, or partial defoliation from recurring fires.

Seedlings subjected to adverse conditions become stunted and eventually die.⁴ In general, survival depends largely on the capacity of seedlings to emerge from the grass fairly promptly. Exclusion of fire means chiefly that competition from other vegetation is intensified, thus smothering the seedlings, or that brown-spot needle disease spreads and becomes lethal. Brown spot normally approaches a peak over a period of years. It spreads slowly when a previous scarcity of seedlings has left little or no longleaf foliage in the highly susceptible zone 1 or 2 feet above ground. Fire is useful in reducing the disease, but burning every year is too hard on the seedlings, largely because it prevents retention of the needles through the second year. Second-year foliage is essential to thrift.

Extensive areas of successful natural regeneration on national forests indicate that longleaf can reproduce well under frequent burning and then grow well without the benefit of fire. In fact, the sapling and small-pole stands have improved in thrift and rate of growth in response to relief from too frequent burning. If disastrous accidental fires can be avoided, there may be no pressing need for the further use of fire until the second growth is harvested to make room for the third generation of longleaf.

Longleaf pine holds its ground most easily on the higher, drier, frequently burned sites remote from the seed supplies of competitors. As already noted, fires that consume surface debris usually kill to the ground low vegetative cover other than longleaf. Above that level, green foliage is destroyed to variable heights, but usually to not more than twice the height of the flames. The small stems of most hardwood associates are fire-killed more readily than pine, but many of these associates are prolific sprouters, even from relatively large stems. Served by extensive root systems left intact by the fire, hardwood sprouts grow rapidly and may reach 5 to 15 feet or more before longleaf seedlings of the same age can emerge from the grass. This sprouting capacity enables hardwoods to suppress longleaf reproduction in many places, a condition that is aggravated by the intolerance of longleaf for an overstory of any kind. Overtopping slowly but surely kills longleaf seedlings.

The species can therefore retain its hold on the lower, moister sites, as on the borders of streams and ponds, only when competitors are set back by fire or cutting. In hardwood thickets most longleaf seedlings die before they can start height growth.

Hardwood invasion has been extensive on many heavily cut areas not promptly reproduced to pine. Patches of scrub oaks are common in second-growth stands, but the better-stocked areas have not yet deteriorated seriously in species composition. Any increase in hardwood weed trees of fire-resistant size, however, may add to the difficulty of establishing a third generation.

⁴The specific effects of many adverse conditions are discussed in Chapters V, VI, and VII.

EFFECTS OF FIRE ON SOIL, DISEASE, AND INSECT ACTIVITY

Nitrogen, Minerals, and Organic Matter

The effects of frequent burning on the chemical composition of surface soils are slightly beneficial.

Nitrification is stimulated by the abrupt liberation of ash as a result of fire; potash, calcium, and other minerals in the ash are returned to the soil in readily available form. This, according to Harper (242), and Sellards, et al (492), achieves a quick turnover that permits pine to "do a large business on small capital." In the South, however, the rate of decay of forest litter and the decomposition of soil minerals is probably rapid enough to release most of the plant nutrients currently needed. Furthermore, ammonification may be more active in unburned soils.

Grass and weeds remain thicker and the organic matter is slightly greater in burned-over soils. Heyward and Barnette (286) found no evidence that continued burning depleted soil nitrogen or organic matter; on the contrary, there was some indication that fire increased soil organic matter. Strong evidence was found that small but significant increases of total nitrogen (up to 14 percent) followed repeated fires (Fig. 15). The increase in nitrogen was attributed mainly to the addition of organic materials through decay of the roots of heavier grass vegetation within the burned areas. Complete exclusion of annual grass fires from a longleaf pine forest for 10 years in southern Mississippi reduced the growth of grasses and legumes to about half that on adjacent areas burned every winter (221, 587). Exclusion of fire caused a corresponding, though smaller, decrease in soil organic matter to a depth of 6 inches. About 1.5 times as much nitrogen was found in the burned-over soils as in those protected from fire.

On grassy areas the source of organic matter and nitrogen is primarily the decay of plant roots. Litter disintegrating on top of the mineral soil in an open forest adds little or nothing to the productive capacity of the site. The influence of litter is confined largely to those physical effects characteristic of mulch coverings. Fires do not destroy organic matter below the top quarter-inch of mineral soil. With recurrent fires, a type of humus layer more typical of grassland than of forest occurs.

Moisture, Absorption, and Mulches

Moisture is one of the chief factors influencing the growth of longleaf pine because of the small capacity of sandy soils to retain water and the large loss through evaporation and transpiration of the trees, augmented by a long growing season. Fire influences soil moisture by altering the forest floor or vegetative cover, and by modifying the moisture relations of the soil itself. Because the "rough" has a mulching effect, soil tends to be moister on unburned sites to a depth of at least 10 inches than on frequently burned areas (Fig. 15). Heyward (281) found that although the difference was small in absolute amounts, the soil at the 0- to 2-inch depth had over 52 percent more moisture on unburned than on burned areas. The author (587) found surface-soil moisture slightly higher on the unburned portion of a grazed area and on the burned portion of an ungrazed area. On the grazed area the exclusion of fire for 4 years increased the pore space in the upper 2 inches of soil by 1 or 2 percent. The

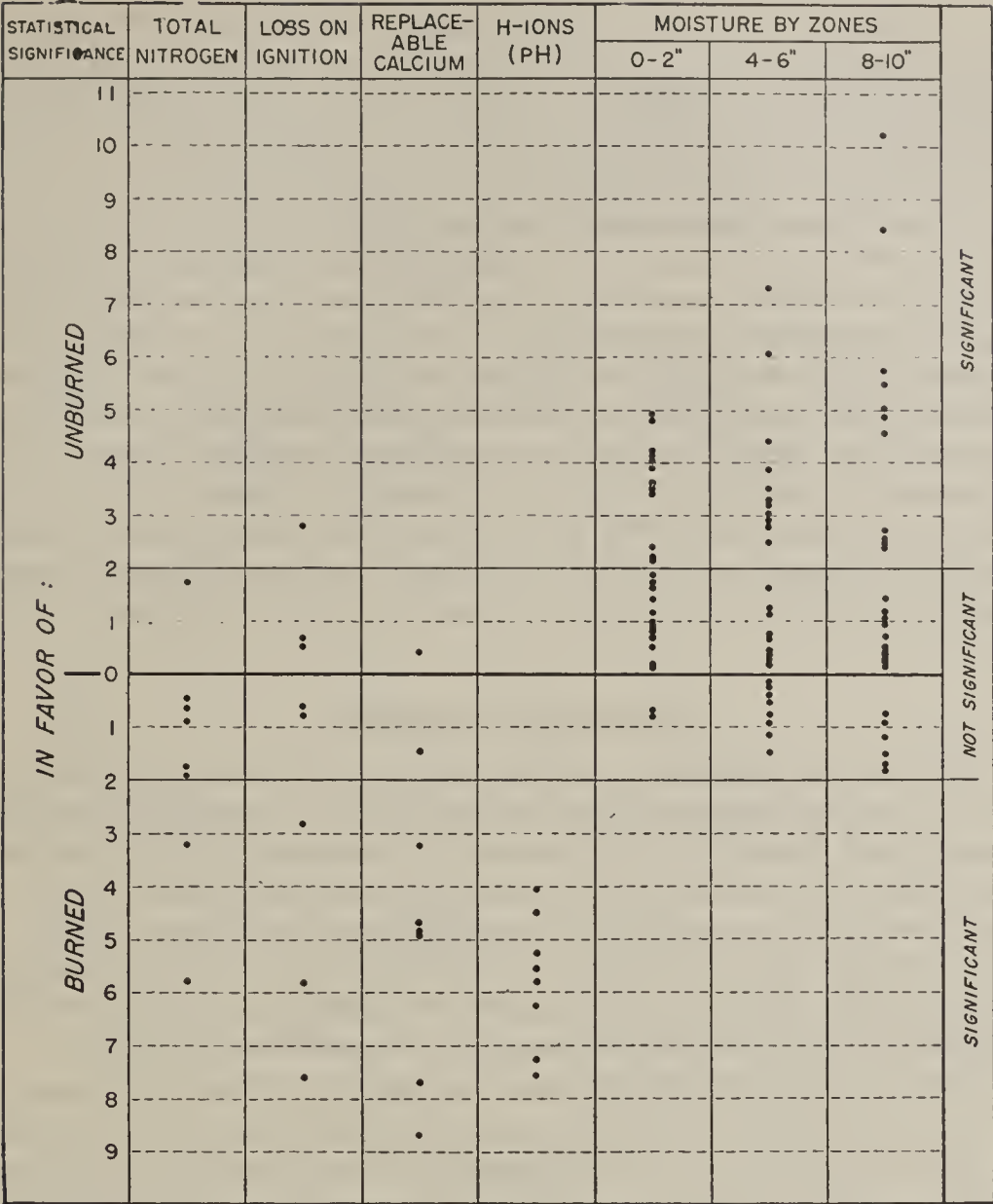


Figure 15.—Effect of burning on soil moisture and fertility. Each dot represents the difference between two soil samples taken in comparable burned and unburned stands. The degree of statistical significance is measured by the mean difference divided by the standard error of the difference. When this value is 2 or more, the difference is considered statistically significant.

general tendency for superficial layers to be moister on unburned than on burned areas appears to be due, at least for the heavier soils and sloping sites, to a relatively rapid intake of moisture from, and slow exit to, the atmosphere.

Soil Temperatures

Soil temperatures were recorded by Heyward (283) during 44 experimental fires in a diversity of natural fuel types in longleaf pine forests. His records showed

that "at a depth of $\frac{1}{8}$ to $\frac{1}{4}$ inch, temperatures only slightly higher than those of the air and ranging up to 274° F. occurred. Maximum temperatures over 200° F. were infrequent, the majority ranging from 150° to 175° F. These temperatures generally persisted for 2 to 4 minutes, after which they declined rapidly. Soil temperatures at the $\frac{1}{2}$ -inch depth were much lower than those at $\frac{1}{8}$ inch."

Although flames burning before the wind are often 10 feet high or more, and may scorch the crowns of trees 50 or 60 feet high, the temperature in the upper quarter-inch of soil remains comparatively low. Such fires do not last long enough to permit the penetration of much heat into the soil at any one spot. Higher surface-soil temperatures, however, may result when the same light fuels are burned slowly against the wind. But the heat generated by even the hottest fires cannot raise temperatures at a soil depth of $\frac{1}{8}$ to $\frac{1}{4}$ inch to a point destructive of organic matter. No recorded soil temperature in Heyward's experiment approached charring levels for dry organic matter (350° – 400° F.).⁵ He concluded that most forest fires in the longleaf pine region do not heat the soil sufficiently to impoverish it; on the contrary, considering the effect of heat alone, fires tend to release plant nutrients in usable form.

Mechanical Penetrability

The surface of frequently burned-over longleaf soils becomes hard from exposure to sun, rain, and the trampling of grazing animals.⁶ Over 13,000 instrumental tests were made during 1930-31 to measure the cumulative effects on mechanical penetrability of 8 years of annual burning and grazing near McNeill, Miss. Unburned sites showed universally greater penetrability than did burned areas. The surface of the burned-over soil varied from slightly harder to 5 times as hard as that of unburned soil. In respect to grazing, the data showed that the soil varied from slightly harder to 6 times as hard on grazed as on ungrazed areas (Fig. 16).

The undesirable soil conditions found on sloping and frequently burned surfaces may be avoided by excluding fire, or ameliorated by using fire less frequently and more moderately. In this way, superior surface-soil conditions may be maintained or restored to longleaf sites, the desired changes being induced largely by increasing the number of soil organisms (282). In closed pine stands with fire excluded for 10 years, the ground cover is smothered out by a forest floor 2 to $3\frac{1}{2}$ inches thick. Active soil fauna make the A_1 horizon penetrable and porous; a crumb structure develops, and the humus layer assumes characteristics intermediate between mull and mor.

⁵Although the thermal conductivity of soil increases with moisture up to a certain percentage, surface fires do not raise the temperature of moist soil above that of dry soil. Owing to the very high specific heat of water, the rise in temperature is even less in a moist soil.

⁶Concentration of cattle on open areas tends to compact the soil, as shown by 180 penetrometer readings on the Harrison Experimental Forest in southern Mississippi. When the penetrability of a burned area heavily grazed for 6 months was taken as 1, the penetrability in an old-field pine stand was 8, and that of an open grassy area unburned for 3 years or more was 10. Maki, T. E. The influence of cover type on surface-soil compactness. 1937. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

Microfauna

The same kinds but not the same numbers of microfauna are found in soils protected from fire as in those exposed to periodic burning. In the areas tested by Heyward and Tissot (288) the upper or A₀ horizon of unburned soils contained approximately five times as many micro-organisms as the ground cover of burned areas. The top 2 inches of mineral soil of unburned forest had 11 times as many organisms as the corresponding soil zone of burned areas.

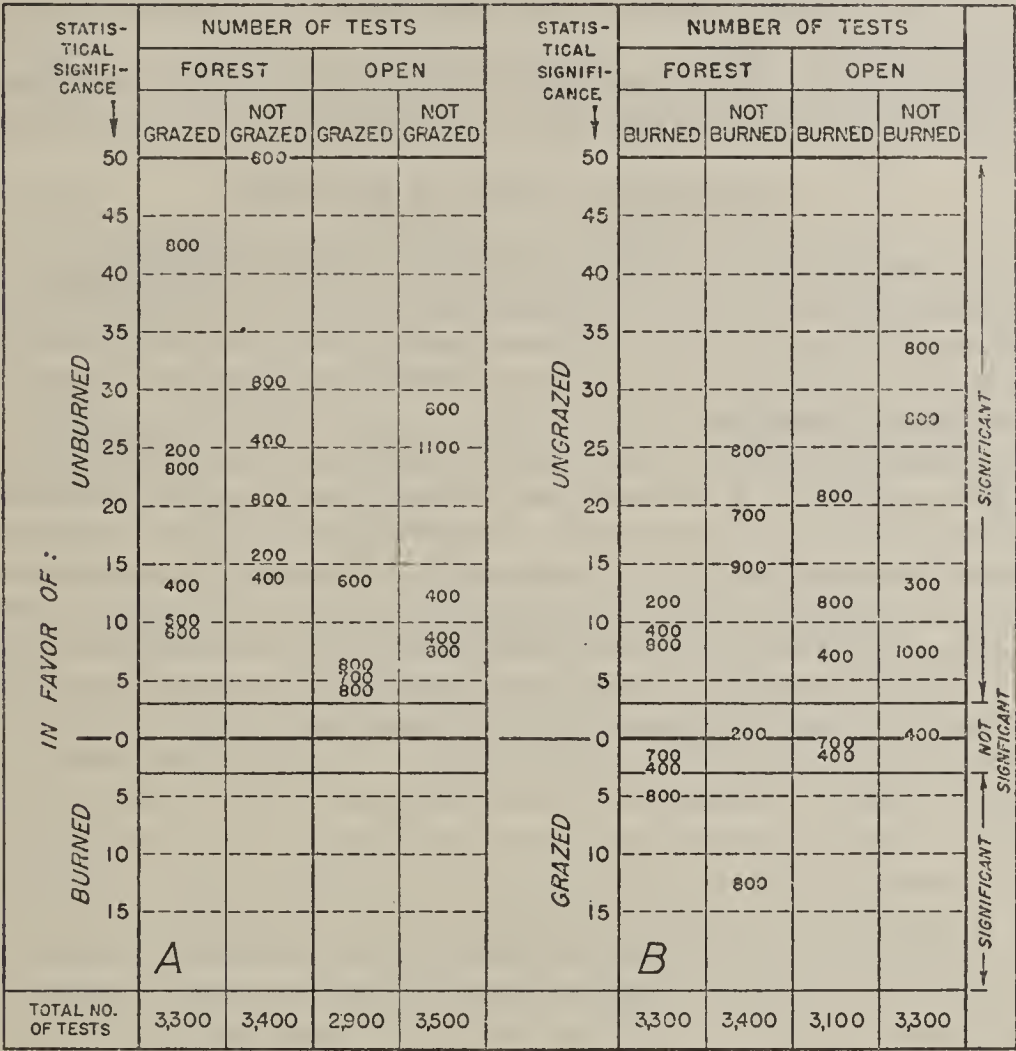


Figure 16.—A, effect of burning, and B, effect of grazing on mechanical penetrability of surface soils. Each panel shows the number of tests, the treatment that gave the greater penetration, and the degree of statistical significance as measured by the mean difference divided by the standard error of the difference.

Unburned soils were riddled with holes and tunnels of small mammals and insects, a condition generally absent on frequently burned areas. Probably 80 or 90 percent of the mammalian tunnels in the first inch or two of soil were dug by pine mice, which feed on the roots of shrubs. Earthworms were far more numerous in unburned than burned localities. Mites were by far the most abundant micro-organ-

isms in protected soils. Diversified, active microfauna are probably responsible for the penetrable and well-aerated soil of unburned forests, in striking contrast to the more compact, less porous soil of frequently burned areas where there is much less microfaunal activity.⁷

Disease and Insects

Frequent burning helps to reduce the brown-spot needle disease. Fire treatments for this disease should be prescribed only where the need for sanitation burning is clear, but badly diseased areas should be burned every 2 or 3 years until the seedlings emerge from the grass.

Severe burning weakens some trees enough to increase their susceptibility to insect attack, but moderate burning seems to have little effect on the work of insects.⁸

COMBINED EFFECTS OF FIRE

It is clear that fire must have played a vital role in the development of the original pure longleaf pine forest. Fires profoundly affect the composition of forests—the relative abundance of the component species. The result at any one place depends upon the relative resistance of the associated trees. Longleaf is injured less than any other southern pine.

Fire holds down, tends to reduce, but by itself seldom completely eliminates understory vegetation. In the more open unburned stands and on moist sites in closed stands, herbaceous ground cover often gives place to a heavy understory of deciduous shrubs and trees. If fire continues to be excluded and hardwood seeds are available, the broadleaved understory invades more and more of the higher ground, developing a tall undergrowth and displacing nearly all herbaceous plants. Then, when drought occurs, the usual sources of moisture tend to dry up and can no longer supply both over- and understories. If the soil is too dry to a depth of 3 or 4 feet, the pines may be attacked by *Ips* engraver beetles. In contrast, the moister soil of frequently burned forests maintains the natural resistance of pine to insects. Thus a sequence of related events may carry a pine stand through less fire, more brush, less moisture, more insects, and finally fewer pines. This cycle need not be repeated often to approach the natural, but undesirable, upland "hammock" climax forest type. The succession can be checked by prescribing suitable burning treatments.

Stands that are already established can be brought to maturity without fire, though it may be difficult to avoid deterioration in species composition that will depreciate the value of subsequent timber crops. For example, 51 long-unburned forests of longleaf and slash pines widely distributed over the longleaf region, from South Carolina to Louisiana (285), were compared with nearby forests subjected to repeated burning. Table 12 shows that exclusion of fire ultimately resulted in an invasion of hardwoods. Sweetgum, water oak, and laurel oak were especially ag-

⁷In a region characterized by rapid decomposition of organic matter, as in the longleaf pine forests, the fact that microfauna increase organic matter or nitrogen is not always obvious. The well-aerated condition of the soil, brought about largely by the fauna, tends to accelerate organic decomposition as well as the prompt loss of nitrogen in forms available for absorption by trees.

⁸The detailed behavior of disease and insects in relation to fire and other factors in longleaf regeneration is discussed in Chapter IX.

Table 12.—Changes in species composition on sites originally occupied by longleaf pine, under freedom from fire for 12 to 75 years (285)

Species group	Seedling repro- duction	Distribution of trees by diameter groups (inches)					Total trees	
		1-3	4-8	10-14	16-20	22 & up	Long unburned	Frequently burned check
Average number per acre								
UNBURNED 12 YEARS (FLATWOODS NEAR GAINESVILLE, FLA.)								
Pines other than longleaf	0	5	20	65	5	0	95	0
Various oaks	125	1,110	0	0	0	0	1,110	0
Other hardwood trees	1,250	840	20	0	0	0	860	0
Total associates	1,375	1,955	40	65	5	0	2,065	0
Longleaf pines	0	0	70	75	0	0	145	---
UNBURNED 12-15 YEARS (CULLED VIRGIN STAND, UPPER COASTAL PLAIN, ALA.)								
Various oaks	170	390	0	0	0	0	390	0
Other hardwood trees	380	740	0	0	0	0	740	0
Total associates	550	1,130	0	0	0	0	1,130	0
Longleaf pines	0	0	10	20	30	20	80	---
UNBURNED 20 YEARS (FLATWOODS NEAR LAKE CITY, FLA.)								
Pines other than longleaf	0	4	26	74	28	0	132	---
Various oaks	20	36	18	0	0	0	54	0
Other hardwood trees	80	256	32	0	0	0	288	0
Total associates	100	296	76	74	28	0	474	0
Longleaf pines	0	0	8	6	0	0	14	---
UNBURNED 25 YEARS (UPPER COASTAL PLAIN, SUMMERVILLE, S. C.)								
Pines other than longleaf	70	107	22	2	0	0	131	0
Various oaks	4	18	0	0	0	0	18	4
Other hardwood trees	73	86	15	0	0	0	101	0
Total associates	147	211	37	2	0	0	250	0
Longleaf pines	12	105	289	87	0	0	481	---
UNBURNED 30 YEARS (FLATWOODS NEAR CHIEFLAND, FLA.)								
Various oaks	0	26	94	6	0	0	126	0
Longleaf pines	0	76	90	0	0	0	166	---
UNBURNED 75 YEARS (FLATWOODS, CUMBERLAND ISLAND, GA.)								
Pines other than longleaf	0	0	0	0	0	0	0	(2)
Various oaks	0	5	3	6	1	6	21	(2)
Other hardwood trees	0	175	54	4	0	0	233	(2)
Total associates	0	180	57	10	1	6	254	
Longleaf pines	0	1	13	11	27	13	65	(2)

¹Zeros signify that absence was noted, while a dash indicates merely that no count was made. Thus it will be seen that all the burned check plots were pure stands of longleaf pine except the one near Lake City which contained other pines but no hardwoods or shrubs. The 4 oaks in the burned area in South Carolina were 4-inch and 8-inch blackjacks, *Quercus marilandica*.

²No adjacent check plot available.

gressive in occupying longleaf sites protected from fire. When hardwoods become established under a stand of pine at least 25 to 30 years old, no troublesome silvicultural problem is presented until the pine is ready to be harvested. Before harvesting longleaf pine, it is necessary to consider all the possible means of subduing or eliminating the hardwoods until adequate pine reproduction has been obtained. Unless such measures are taken, a pronounced change from pure pine to mixed pine-hardwood forest will eventually occur under fire protection.

Most of the hardwood associates of longleaf do not have much commercial or soil-building value. Dogwood occasionally reaches commercial size in sufficient quantity and quality to warrant cutting. Southern red oak also has potential market value, although it is worth little as yet when grown on longleaf land. Probably all vegetation, however, benefits the soil through the decay of dead roots if not in other ways. As a soil builder, dogwood is excellent, and sweetgum and blackgum may be of value, but oaks are almost worthless.

From the forestry standpoint, there appears to be no present justification for having a hardwood component in longleaf stands. One promising method of reducing these hardwoods is the use of controlled fire. Where hardwoods exceeding 2 inches in diameter are present, they may be cut, but this is seldom done in understories because of the cost and the resultant sprout growth. The sprouts which develop after such cutting, however, might be kept in check by proper burning technique.

Lands subject to erosion should not be burned frequently. Since the culture of longleaf calls for some use of fire, it may be wise on very erosive areas to permit other species to replace longleaf, or at least to lengthen the interval between fires. Erosive soils are best held in place by vegetative types which can persist without the aid of fire. The occasional light burning of longleaf stands leaves an herbaceous ground cover thick enough to prevent much washing away of soil. Hence, except where erosion is a serious problem, the maintenance of soil productivity in the longleaf type should not be difficult.

SUMMARY

Until early in the 20th century virtually all longleaf pine stands were burned over at irregular intervals, averaging perhaps five times in a decade and covering about 90 percent of the surface every 3 or 4 years. Whether started by lightning, Indians, or settlers, most of the fires were of the surface variety. In recent years fires have also been relatively light except where long intervals between fires occurred.

Soil changes induced by fire are of two principal kinds: (1) slightly beneficial chemical effects, and (2) somewhat detrimental physical effects. Both effects are largely indirect, resulting from the various responses of the burned-over plants to fire. For example, the supply of humus seems to depend largely on the growth and decay of grass roots rather than on surface conditions. Where the forest is free from a dense hardwood understory, surface layers of soil tend to be moister on unburned than on burned-over areas, in part because they absorb rain water rapidly, and in part because a mulch of accumulated vegetal debris helps to retain soil moisture. Most forest fires in the longleaf region do not heat the soil sufficiently to impoverish it, although repeated fires expose and compact the soil surface. Burned-over compacted soils tend to erode rapidly, an effect that should be considered in any proposed use of fire on sloping ground. There is evidence that satisfactory soil surfaces and the present level of soil productivity can be maintained with moderate burning treatments suited to longleaf pine culture.

Heavy cuttings, particularly if followed by the reduction or elimination of burning, have permitted many longleaf sites to be captured by other, often inferior, tree

species coming in either from windborne seeds dispersed from neighboring sources or from the vigorous growth of a formerly suppressed understory. Scrub oaks are the most common weed trees, and many large areas in the longleaf type have been converted to scrub oak. Most of the hardwood associates are of poor form and quality, and have little or no utility, but pine associates of longleaf are commercially valuable.

Fire affects five out of the six conditions that prevent successful natural regeneration. Fire removes barriers that keep seeds from contact with mineral soil, retards the spread of defoliating disease, prevents smothering by consuming dead grass, and restricts the encroachment of other species. The destruction of seeds by birds and animals, however, is facilitated by fire. The sixth condition, suppression by an overstory, must be removed by other means than fire if reproduction is to be successful. On the whole, longleaf pine has inherent adaptations that make it more fire hardy than any associates, and under periodic burning it survives because of reduced vegetative competition.

The extensive pure longleaf pine forests of the South have not been entirely uninjured by fire but they are thoroughly inured to it. In fact, they are so dependent upon fire that their normal life cycle cannot continue without its influence. Hence, the use of some fire is necessary in the culture of longleaf, although there is a wide range between the maximum which it can endure and the minimum it requires. Longleaf can stand annual surface fires except in the cotyledon and early grass stages. It needs fire treatments during the short period just preceding and during the process of regeneration. After a sapling or pole stand is firmly established, it thrives under total exclusion of fire, but the risk and expense of prolonged fire exclusion can seldom be justified. Burning, however, should be prescribed only after careful consideration of the local situation.

Part 3. REGENERATION

V. Seeds, Seedbeds, and Seedlings

SEEDS

Flowers

NORMALLY longleaf pine does not bloom until the sapling or small-pole stage is reached, and flowers are abundant only in certain years and on certain thrifty open-grown trees. The minimum age for the production of pistillate flowers is tentatively placed at nine years (469).

The staminate, or male, pollen-producing catkins may first appear in December and the pistillate, or female, cone-producing flowers somewhat later, perhaps not until February. Both kinds of immature flowers are inconspicuous. The anthers of the staminate and the scales of the pistillate flowers are purplish (19). Staminate flowers grow in clusters between the preceding year's needles and the new bud, i.e., at the base of the current year's twigs. At maturity they are heavily laden—75 percent by weight—with yellow pollen. Staminate flowers appear on nearly all stems of the crown of a flowering tree except the most vigorous twigs at the top and on the stronger side branches. On these sturdier twigs pistillate flowers develop at the tip of the first node.¹ Male and female flowers are shown in Plate 5.

Pollination takes place from February to April, but most profusely in March. The pollen is disseminated by wind, usually in March. Pistillate flowers are receptive to pollen for only a brief period. Furthermore, male and female flowers on the same tree do not always mature at the same time. Sometimes a tree sheds its pollen before the pistillate flowers open to receive it. Thus the earlier maturity and lower location of staminate flowers discourage self-pollination and may account for the failure of some trees to produce abundant seed.

Cone Production

There is some evidence that yield of sound seed per bushel of cones is less in a light than in a heavy cone crop. The loss of immature cones, or the maturing of cones which produce only empty seeds, has often been attributed to lack of pollen. Yet tests have failed to indicate greater quantity or superior quality of seeds from the cones of trees so grouped as to have an abundance of pollen. Cones are larger from second-growth trees than from old growth. Old-growth trees 200 feet beyond the sources of pollen sometimes have the smallest cones. Cones from young

¹The seasonal shoots bearing staminate flowers are short; those without flowers, intermediate; and those with pistillate flowers, long. During the growing season, the elongation of shoots bearing staminate flowers varies inversely with the number of flower clusters. This suggests a retardation of stem growth as a result of pollen production. On the other hand, the production of pistillate flowers apparently stimulates the growth of shoots that bear them, for they are always larger than flowerless shoots (439). Obviously the thrift of shoots and sex of flowers are correlated, though which is cause and which effect is not entirely clear.

trees yield fewer seed per pound than those from old trees. Young trees, however, usually produce as good seed as old trees.²

Mathews (382) has noted some apparently unique structural and functional characteristics of the fertilization process in longleaf. Fertilization takes place 14 months after pollination. This unusual delay keeps the delicate sperm cells imbedded in alien tissue for a long period and may be responsible for some of the vagaries of seed production. Following Ferguson's account of the embryology in pines (171), Buchholz (59) reported that pines are morphologically polyembryonic. Usually multiple embryos are found in immature seed in July, though only one remains when the seed matures in September. However, in tests conducted by the Forest Service less than one percent of longleaf seeds were found to contain multiple embryos. Where there were two, they were occasionally of equal size and both capable of continued life, although one usually was small and weak.

Cones scarcely increase in size during the summer, fall, and winter after pollination, but make rapid progress in their second spring. Early in the second summer they attain full size (Pl. 5), and ripen in the following October (occasionally in late September). Usually they open on the trees between October 20 and November 10. Seed fall in any one year, however, may come at different times in different localities. One year, longleaf pine cones in southern Jackson and Harrison Counties, Miss., near the Gulf Coast, shed their seed from the middle of September to early October, whereas in Pearl River County, 40 miles inland, seed was shed from about October 10 to the end of November.

In a heavy seed crop, from 85 to 95 percent of the trees bear cones; in a medium seed fall, 65 to 85 percent; and in a light fall, less than 65 percent. The number of cones per tree follows a similar trend. In a heavy seed fall, about half the trees will bear more than 50 cones each, but in a medium year only 20 percent will bear that many, and in a light year only 5 percent.

For natural as well as artificial seeding it is important to know when to expect a bountiful seed crop. Heavy longleaf seed crops have been reported for various localities in 1845, 1872, 1892, 1907, 1913, 1919, 1920, 1921, 1928, and 1935; medium crops occurred in 1916, 1921, 1922, 1924, 1929, and 1939; and light crops in 1927, 1929, and 1931. The indicated irregularity may be due not so much to the absence of rhythm in nature as to inadequate reports. Not until recent years has there been any attempt to make systematic observations on pine seed years.

The Southern Forest Experiment Station has summed up longleaf seed-crop production between 1931 and 1941 as follows:

- 1931. Generally good; very light in Texas.
- 1932. Generally light.
- 1933. Poor, except for fair production in southern Mississippi and southeastern Louisiana.
- 1934. Good from southern South Carolina south to northeastern Florida and west to southeastern Louisiana; moderate to light elsewhere east of the Mississippi River; failure west of the river.
- 1935. Generally good to heavy.
- 1936. Definitely poor to spotty.
- 1937. Moderately good in northeastern Florida and southeastern Georgia; spotty, light, or poor elsewhere.

²Maki, T. E. Cone size and seed yields in relation to isolated and grouped longleaf pines. 1937. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.] Loblolly frequently pollinates flowers of longleaf pine, producing from 0.5 to 6.0 percent hybrid seeds (*Pinus Sondereggeri* Chap.).

- 1938. Fair to medium in southeastern Mississippi and light to medium in central Louisiana. Elsewhere light, poor, or very poor.
- 1939. Fair to good over range of species, except rather light west of the Mississippi River and definitely poor and spotty in northeastern Florida and southeastern Georgia.
- 1940. Light to fair over most of the range; poor or failure in central South Carolina, east-central Mississippi, central Alabama, and most of Florida.
- 1941. Very poor to failure in Texas, Louisiana, and most of Mississippi and Alabama; light to fair near the Atlantic and Gulf coasts.

In a given locality longleaf pine bears irregular seed crops. Good crops often occur every 5 to 7 years and failures about 1 year out of 5, but exceptions are so common that no specific interval can be relied upon. Furthermore only bumper crops are large enough to feed the wildlife and simultaneously provide for pine reproduction.

In addition to the character of the seed year, the main factors that influence the seed yield of a tree are: (1) time—the seed year and age or size of tree; (2) environment—quality of soil, climate, and exposure to injurious agents such as bad fires or severe turpentineing; (3) heredity; and (4) spatial factors, like degree of crowding and the resultant growth rate and crown development.

Longleaf pines, even in open stands, usually do not bear cones until they are 20 to 30 years old (12, 113). Appearance of flowers at 9 years and cones at 16 is unusual (442). Some pole-size trees bear seed. Closely grown trees, young or old, are not prolific until some time after release; they become more fruitful with unrestricted development of their crowns.

Effects of Soil Fertility

There is evidence that both drainage and type of soil affect seed yield. Thus, cone production between 1927 and 1932 in southern Mississippi was 16 to 50 percent greater on well-drained upper slopes or ridge tops than on moister sites. Production was best on Orangeburg, intermediate on Norfolk, and poorest on Ruston soils.

Cone production from second-growth trees may be slightly higher on burned than on unburned land, but in general the recorded differences are slight (Fig. 17 and Table 13).

Table 13.—Effect of crowding on diameter growth and cone production of second-growth longleaf pine¹ (After Bull)

Treatment and tree size ²	Isolated			Surrounded			Crowded		
	Trees	6-year growth	Cones per tree	Trees	6-year growth	Cones per tree	Trees	6-year growth	Cones per tree
	Number	Inches	Number	Number	Inches	Number	Number	Inches	Number
Unburned 10 years:									
8 inches d.b.h.	3	2.5	0.7	16	2.4	1.7	15	2.1	1.1
9 inches d.b.h.	14	2.8	3.2	25	2.6	2.5	10	2.5	1.5
Total or average	17	2.7	2.8	41	2.5	2.2	25	2.3	1.3
Burned annually:									
8 inches d.b.h.	6	2.0	2.3	17	2.2	1.3	16	1.9	1.6
9 inches d.b.h.	8	2.3	4.0	12	2.3	2.8	6	2.0	1.2
Total or average	14	2.2	3.3	29	2.2	1.9	22	1.9	1.5

¹Cone production is averaged for the years 1927, 1929, 1931, 1932 and 1933. The trees were in natural stands on cut-over land in southern Mississippi. It is not known whether these trends hold as well for the heavy cone crops of good seed years.

²July 1933.

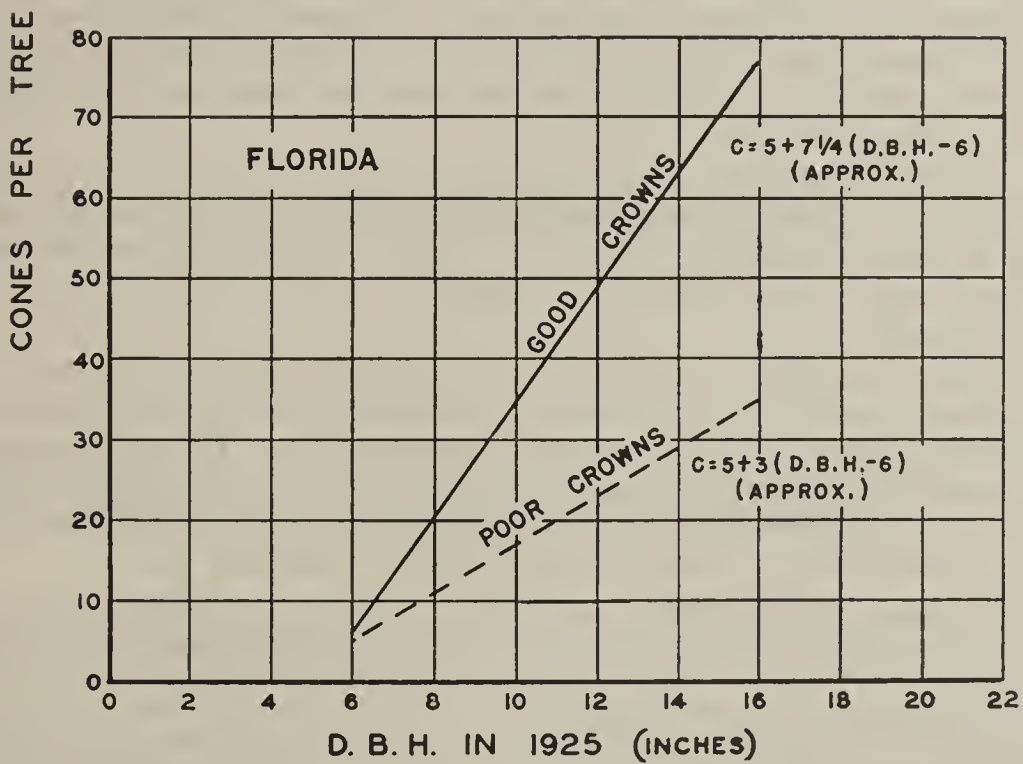
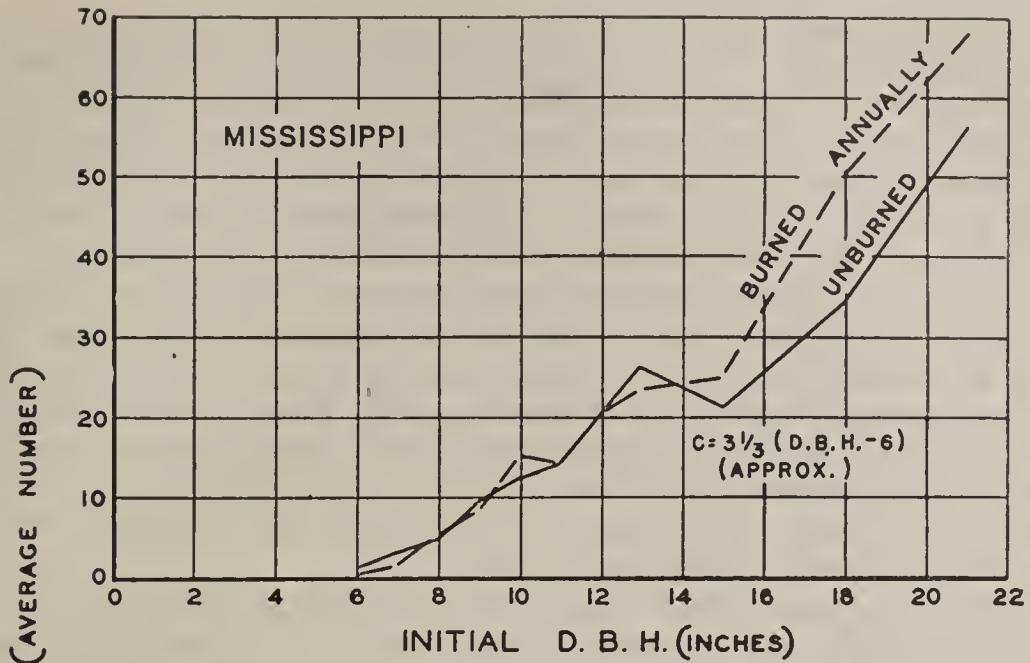


Figure 17.—Cone production of longleaf pine as related to diameter of tree. Upper panel shows superior cone production from trees above 14 inches d.b.h. on annually burned lands; lower panel, superior production from trees with good crowns. Mississippi study based on 4 years of medium or light production; Florida study, 1 heavy seed year. (After Bull and Demmon)

Apparently anything that stimulates growth of longleaf on poor soils also increases its fruitfulness. After a 5-year test of fertilization and watering on the deep sterile sands of the Choctawhatchee National Forest in Florida it was found that cone production was 7 to 30 times as great as on untreated plots. Thus, the average numbers of cones produced per tree (in 1931) were as follows: with no treatment, 2; mulch, 11; sodium nitrate, 16; irrigation water, 25; sodium nitrate and water, 54; and complete fertilizer with water, 62 (199).

From this it might be assumed that anything which retards tree growth also decreases seed production. Table 13 confirms this conclusion as far as it goes. Since it can be readily shown that turpentine retards the growth of longleaf, the question may be raised whether it also reduces cone yields. Actually, cone counts on the Choctawhatchee failed to show marked differences in productivity between turpentine and unturpentine trees. Counts made near Starke, Fla., brought the same conclusion. Seemingly, the reduction in food supply caused by chipping does not seriously interfere with cone formation (630).³

Study of variously shaped crowns of residual old-growth trees fails to reveal a basis for anticipating cone yields. Average cone yields rise sharply with increase in diameter of trees. Figure 17 suggests that it may be possible to evolve formulas for approximate yields in given places and years. The spread in yields between larger trees with good or poor crowns (Fig. 17, B) shows that fertility varies widely within diameter classes (Fig. 18). The meager cone production from trees below 10 to 12 inches in diameter is evident.⁴

In 1928 in eastern Texas few longleaf pines below 10 inches d.b.h. had cones, while about 90 percent of those above 10 inches bore cones. Trees under 10 inches d.b.h. seldom bore more than 20 to 25 cones. Trees with large thrifty tops were most prolific. Several large old trees, left in logging because of red heart, bore up to 170 cones each.

Earlier observations on the virgin forest in Alabama indicated that small crops of seed were borne by thrifty poles 10 to 12 inches in diameter (60 to 85 years old), but not in sufficient quantity to insure ample reproduction. The suppressed poles were usually long and spindling and often had a short-tufted or scraggly one-sided crown. Only a very small percentage of suppressed trees bore cones. The most fruitful trees were from 16 to 24 inches d.b.h. (100 to 175 years old) (58).

The secret of high yields is not known. However, some trees are so much better seed producers than others that they should be marked during seed years and

³Foreign experience indicates that the production of heavy, viable Scotch pine (*Pinus sylvestris*) seeds is more prolific when the trees are not worked for gum. Comparison of seed yields showed that "cones of untapped trees averaged 50 percent heavier and contained 44 percent more seed; also, seed from untapped trees weighed 30 percent more than those from tapped trees, and had a percentage of germination of 82 percent as compared with 64 percent for seed from tapped trees. The cones, seed, and seedlings from tapped and untapped trees differ in appearance" (88).

⁴In one case in 1929, however, more than 2 bushels of cones containing some 9,000 seeds were collected from one 9-inch tree in Alabama. In another case, an open-grown sapling in Mississippi, starting to bear at an unusually early age, matured 221 cones in 1927, when it was only about 6 inches d.b.h. No injury or other plausible explanation was detected at that time. An examination in 1940 showed a radial growth, inside bark, of 3.6 inches in 20 years (1920-39) with annual rings averaging 0.18 inch wide. In 1927, however, it grew only 0.14 inch in radius or 78 percent of the average. Exceptional mass production of cones in early life retarded wood growth during the year of seeding.

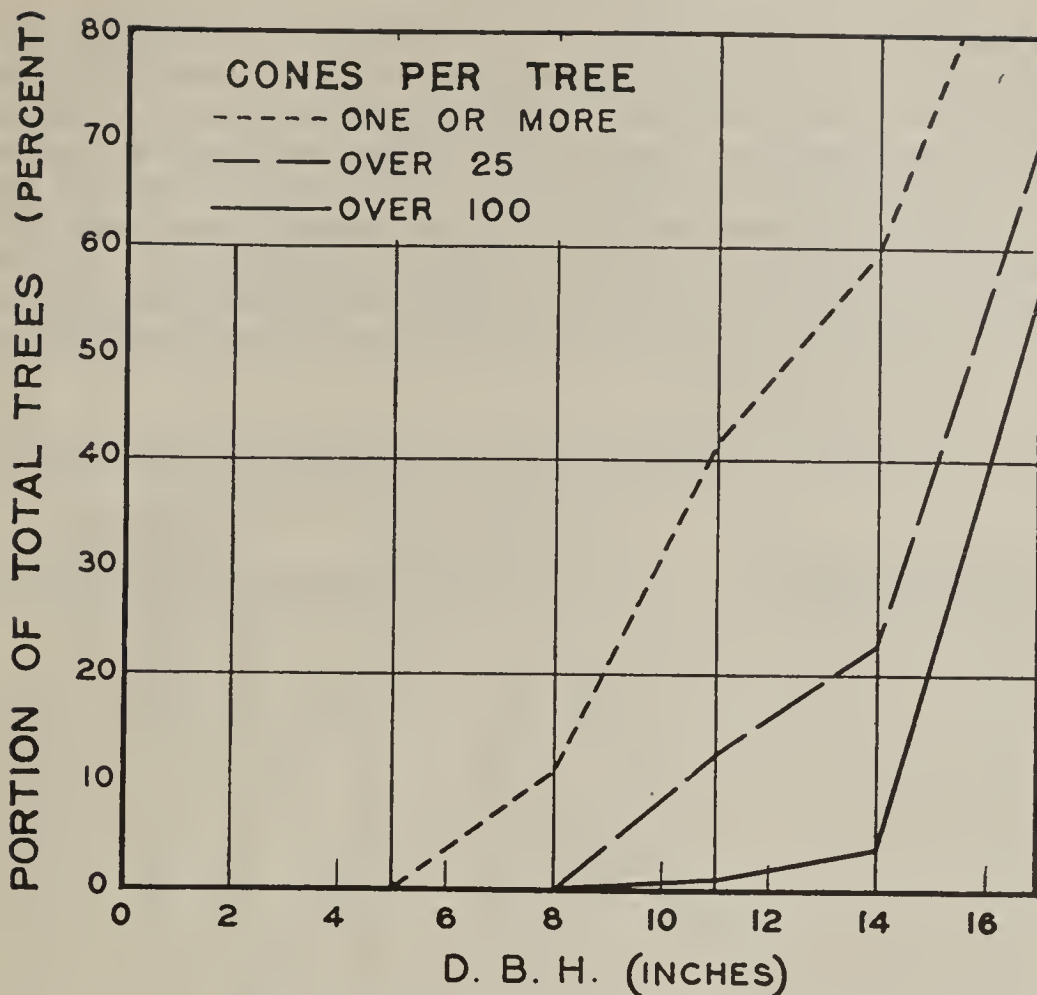


Figure 18.—Variation in cone production of longleaf pine in relation to diameter of tree. (After Bull)

saved in the final cutting in order to utilize their seed-producing capacity in regenerating the stand, and possibly to transmit this capacity to their progeny.

Seed Trees

Any tree that bears seed may be called a seed tree, but certain characteristics usually identify individuals as good seed bearers. Ideally a seed tree is a healthy specimen of a desirable species with a long, vigorous crown and abundant foliage (Pl. 13). Economically, seed trees constitute an investment of a portion of stumpage value in natural reforestation. Legally, a seed tree has been defined in Louisiana as a sound tree of well-developed crown, not less than 8 inches in diameter at 2 feet above the ground.

While an 8-inch tree is too small for seed-bearing purposes, the practice of long retaining veteran trees for seed is questionable. Old trees tend to be prolific, but the investment per acre is relatively high. With improper preparation of natural seedbeds, this investment has often resulted in losses because veterans may contain hidden red heart and are subject to death from lightning, insects, and windfall. Dead

trees cannot always be salvaged before they deteriorate. Decay, as indicated by cat-faces at the base, rotten knots at various points, or "punks" on the trunk, makes wind breakage probable and disqualifies a tree as a good seed bearer. For the same reason, no tree chipped for turpentine can be considered satisfactory as a seed tree.

Round, sound specimens, ranging from 11 to 15 inches, d.b.h. and with ample crown and moderately dense foliage, were the most dependable cone bearers on the Choctawhatchee National Forest in Florida (Table 14). Larger size classes contained proportionately more high producers but smaller totals available for use as seed trees. The number of cones on the ground under a tree is the most reliable indication of the capacity to produce seed.

Table 14.—Cone production of longleaf seed trees in various overlapping 5-inch d.b.h. groups, and proportions of total cone crops in 1920 and 1924 borne by these groups in each production class¹ (After Gemmer)

Cones produced per tree classified by d.b.h. groups (inches)	Percent of all trees in production class			Percent of all cones produced		
	1920	1924	1920 and 1924	1920	1924	1920 and 1924
One or more cones per tree:						
8-12	87	62	68	48	54	53
9-13	90	68	73	51	59	57
10-14	88	72	75	52	59	58
11-15	93	80	89	53	57	57
12-16	92	82	90	48	47	48
13-17	---	86	95	---	---	---
50 or more cones per tree:						
8-12	42	12	18	48	49	48
9-13	46	15	22	54	61	58
10-14	49	18	25	59	71	65
11-15	52	20	31	62	71	67
12-16	54	24	34	59	65	62
13-17	55	23	36	50	46	48
75 or more cones per tree:						
8-12	26	5	10	42	40	41
9-13	28	9	13	48	62	54
10-14	34	12	18	61	89	73
11-15	42	13	23	74	84	78
12-16	46	13	24	74	67	71
13-17	42	17	28	56	61	59

¹Based on counts made on several hundred longleaf pine trees and several thousand cones produced on the poor ridge land of the Choctawhatchee National Forest. Boldface figures are two-crop maxima.

Under optimum conditions, 3 or 4 virgin⁵ trees about 14 inches d.b.h. or their equivalent are needed to restock an acre. If seedbeds are not altogether favorable, 4 to 5 well-spaced seed trees are necessary (58, 99). Four are sufficient where sites have been reasonably well prepared and will be adequately protected. Any number of seed trees may be practically futile on a very heavy rough or a hog-infested or brushy area. Figure 19 suggests that regeneration may fail because of too many as well as too few seed trees. Numerous seed trees offer too much competition to their own progeny. Correction of adverse site conditions is more promising than any material increase in the number of seed trees.

In some instances small and defective old growth left on cut-over lands bore seed after taking 10 to 20 years to recuperate from previous suppression. The good

⁵Lack of data on second-growth seed trees necessitates the use of information on old-growth stands. Since the indicated relationships may be somewhat different in second growth, they can serve only as a general guide.

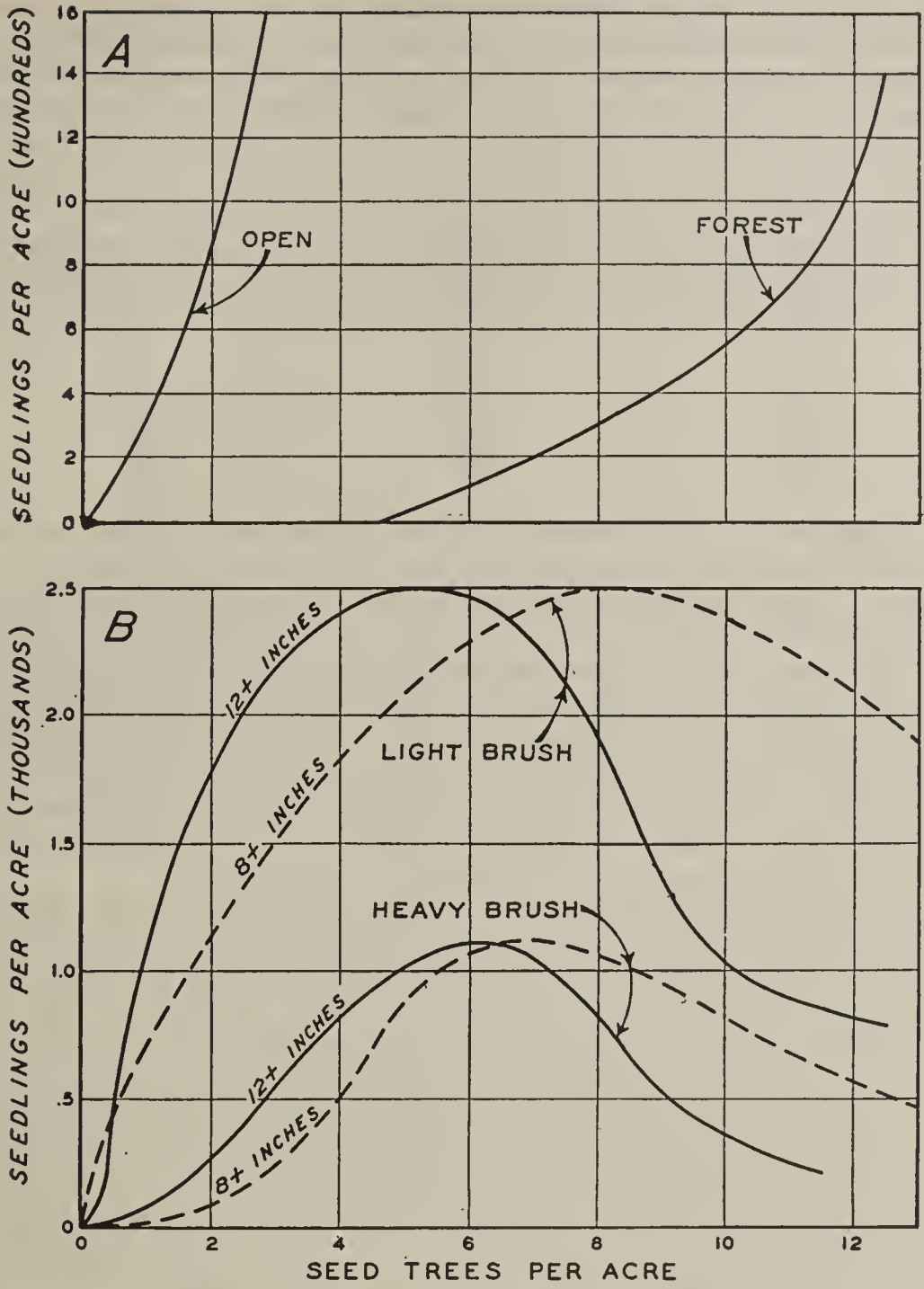


Figure 19.—Density of longleaf pine seedling stand in relation to seed trees and forest conditions, based on extensive surveys in western Florida. (After Demmon)

seeders among these residual trees are indicated in Table 15. Only 20 to 25 percent of the 8-inch trees in some stands can be counted upon to seed abundantly in an intermediate seed year, and not all 10-inch or even 12-inch trees may be good seeders. Only selected trees 10 inches or larger in diameter are dependable seed bearers.⁶

Table 15.—*Percentage of good seeders in longleaf pine stands by diameter classes, 1924 seed crop (After Forbes)*

Diameter breast high (inches)	Southern Mississippi (596 trees)	Southern Alabama (297 trees)
	<i>Percent</i>	<i>Percent</i>
6	6	17
8	22	25
10	54	63
12	67	78
14	78	79
16	91	94
18	83	88

If available, at least 4 second-growth longleaf specimens 14 inches or larger should be left per acre on cut-over areas of more than 5 acres. Where there are insufficient full-sized seed trees, enough smaller trees—for example 6 trees 10 to 13 inches in diameter—should be reserved to produce the same amount of seed. Leaving the smaller trees reduces the investment and increases the chances of survival. In this event, however, more of the surface soil needed by seedlings is monopolized by roots of overstory trees. As seedlings and seed trees cannot occupy the same ground for long, it is necessary to choose between them before the seedlings disappear. In the grass stage the seedling condition and area covered are more significant than numbers. Several thousand seedlings per acre may be worthless unless protected from destruction by range hogs and defoliation by fire or disease.

For trees of seed-bearing size there is evidence that seed production is linked more closely with unrestricted root spread than with available light or crown development. Thus, isolated pairs of trees tend to produce no more than isolated individuals (100). Forty seed trees in groups on 40 acres will leave more space for unimpeded seedling growth than will 4 trees on every acre. When areas are to be reseeded from the side and from trees that are not well spaced, the above estimated number needed to restock a given area is a minimum rather than desirable requirement. When areas are cut clear with the exception of scattered seed trees, regeneration tends to be more uniform if the trees are well spaced. Suppression and border retardation of seedlings, however, will be serious unless the seed trees are promptly removed after serving their purpose. Proper preparation of the seedbed is also essential, regardless of whether the seed source is above or at the side.

Seed Dissemination

If a system of clear cutting in strips or spots is followed, seeds for natural reforestation must come from the uncut sides. The width of the strips is limited by

⁶In the original stands of southwest Louisiana, trees under 12 inches in diameter were rare (481). The deficiency in small trees so common in virgin stands sometimes extended into the size classes suitable for seed trees. Such stands, often possessing only large individuals suitable for seed trees, were usually cut clear. Where seed trees were left, they were seldom properly distributed.

the extent to which seeds can be disseminated effectively by wind currents. The distance of effective dissemination should also be considered in the selection of seed trees in order that they may be properly spaced.

In the fall of 1920 abundant seeding in one area is said to have occurred up to ¼ mile to the leeward of old timber (383). In the calmer atmosphere within the stands the distance seldom exceeded 150 feet (rarely 300 feet) and usually was not over 120 feet, the height of the taller trees. The maximum amount of seed, per square yard, falls between 20 and 30 feet from the base of a tree (71). By means of seed traps the Texas Forest Service observed the following dispersal of seed from an isolated veteran longleaf pine 24 inches d.b.h. and 100 feet high, bearing 150 cones:

Distance (feet)	North Side	Seeds per acre	South Side
66	31,000		15,000
132	21,000		-----
264	8,000		-----
330	-----		6,000
398	1,600		-----
560	900		-----
660	-----		900

Most seeds were carried less than 300 feet and the effective seeding radius of the tree was under 150 feet.

Seeds are scattered according to the direction and velocity of the wind. Those released at a height of 45 feet in a wind blowing about 4 miles per hour have been found to fly from 64 to 115 feet. Gemmer found that seeds blew from 20 to 200 feet in a wind of 5 miles per hour, and at least 100 feet at a 12-mile velocity. Ordinarily the worthless hollow seeds traveled the greatest distance, but one viable seed traveled 900 feet.⁷

When even-aged stands of longleaf are clear-cut up to a definite line, leaving a "wall" of uncut timber as a source of seed, the density of regeneration on adjacent cut-over land diminishes as its distance from the old timber increases. Satisfactory reproduction to a distance of 500 feet, however, as shown in Figure 20, can be attained only when an unusually heavy seed crop falls on a favorable seedbed. Normally, the stand of marginal reproduction is thin and narrow.

There is a temptation to establish a rule of thumb for the dispersal of longleaf seeds and the distribution of seedlings, such as, for example, that on level land seed is scattered to a maximum distance of 1½ times the height of the mother tree, or that the distance of effective seeding equals the height of the tree (58). Numerous exceptions to these rules have destroyed confidence in them, particularly as regards effective seeding.

⁷Gemmer found no significant differences in the weight-area ratios of various species of southern pine seed (longleaf 2.1, loblolly 1.7, and shortleaf 2.0). This helps to explain the uniform results obtained in comparing the seed-dispersal distances of the pines, though tests were insufficient for a conclusive check. The rather dry seeds in one longleaf sample had an average weight of 0.12 gm. and rate of fall of 5.8 feet per second (502). The relation of height to distance in a 4-mile wind has been tentatively expressed as follows: $d = 18.184 + 1.2869 h$, where h = height of release point in feet and d = horizontal flight distance in feet. Such estimates, however, apply only to uninterrupted flights. Actually small groups of scrub oaks or other understory trees intercept the seeds, resulting in heavier seeding under such trees. Knowledge of seed flight is useful in judging future distribution of seedlings. Gemmer, E. W. The flight of longleaf, shortleaf, and loblolly pine seeds. 1940. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

LONGLEAF PINE

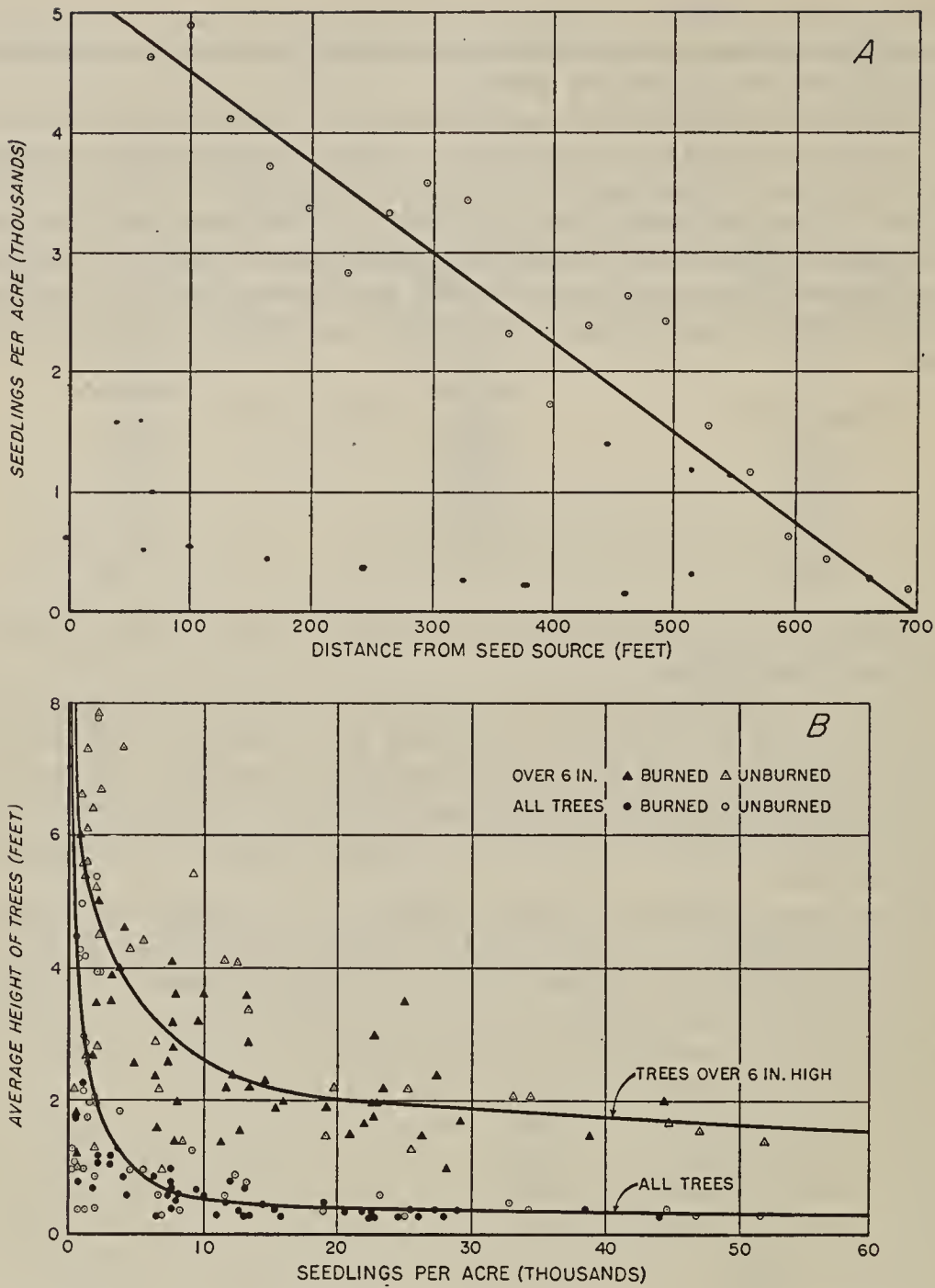


Figure 20.—Density of longleaf seedling stands following natural seeding in a heavy seed year, Washington Parish, La. A, density in relation to distance from seed source (seedlings in thousands per acre averaged $5.25-0.0075 \times$ number of feet from seed source), and B, height of seedlings at different densities. (After Wakeley)

Effective distribution does not depend solely on seed flight. Many other factors, such as the quality of seedbeds and depredation by animals, are vital to production and survival. Unless depredations can be reduced and seedbeds properly prepared, the quantity of seed produced per acre rather than distance of flight will determine the number of seed trees needed to reforest cut-over lands (502). Hence effective dissemination becomes a problem of increasing the efficiency of seeding.

SEEDBEDS

Effective germination does not occur on heavy litter or matted grass; the chief requisite is mineral soil. Retention of wings makes the seed of longleaf more liable to destruction than seed of other pines because of hanging up in grass and litter (592). The chances for germination and early survival are better under a rough than in the open, but growth conditions and subsequent survival are usually less propitious. Vegetal debris, if scarce and thin, may favor germination on longleaf sites.

Like other species, longleaf seeds require moisture in order to sprout; but varying moisture content of the two media in which longleaf germinates—a mineral topsoil or a layer of organic matter—does not account for differences in “catch.” Seeds normally germinate promptly on either surface, often while dependent on atmospheric or self-contained moisture. As they drop from the cones, seeds contain 28 to 29 percent moisture; the kernel itself, 40 percent. Hence germination in partly opened cones, or when seeds are hung up in dead grass, is not uncommon. Without contact with the ground, the germination of seeds is futile because the seedlings soon die from drought or decay. Thus heavy litter prevents establishment because the sprouted seeds do not make effective contact with mineral soil. Unsuitable seedbeds cause serious delay in longleaf reforestation.

Because of the heavy toll taken by fire or drought in the first season, even prompt reproduction may be inadequate for good regeneration. Only a tiny fraction of the seedlings survive their first year (71). Even in nurseries, with prepared seedbeds, cloth mulch, bird guards, weeding, overhead sprinklers, and spraying for brown spot, 40 plantable seedlings per 100 seeds sown is about the best production ordinarily attained. Under the hazardous and adverse conditions on areas to be reproduced by natural means, no such high percentage may be counted upon. Ten seedlings per 100 seeds disseminated may occasionally be attained—possibly even exceeded—but even under favorable conditions, catches of 0.1 to 1 per 100 are much more frequent. It is imperative, therefore, that a seed source be retained adequate to restock the area even with these low tree percents.

The chances of adequate seeding decrease with delay in germination. Old timber absorbs a vast amount of soil moisture and survives the most severe droughts, and as soon as it is cut the still sparsely vegetated site has an excess of moisture available to seedlings. Delayed seeding may permit other vegetation to usurp growing space that was earlier available to seedlings.

Experiments with Natural Seedbeds

Hand sowing has been used to study the processes of natural seeding.

Methods of sowing and variations in the physical condition of seedbeds, above

Table 16.—Seedbed treatments and methods of sowing which affect early germination and "catch" of longleaf pine¹ (201)

Time and method of sowing	Successful spots on seedbed			
	Cultivated	Rough	Burned	All treatments
	Percent			
November 1935:				
In tubes ²	23.3	74.3	40.0	45.9
Mulched	76.3	32.3	57.7	55.5
Drilled	41.0	36.0	82.0	53.0
On surface	32.0	31.3	3.7	22.3
All methods	43.2	43.5	45.8	44.2
January 1936:				
In tubes ²	68.3	91.7	81.0	80.4
Mulched	0	0	0	0
Drilled	32.0	1.0	50.7	27.9
On surface	0	0	0	0
All methods	25.1	23.2	32.9	27.1

¹Autumn and winter sowings were tallied on April 2, 1936. A spot was classed as successful if it contained at least one seedling.

²These were cylinders made of 10-mesh ungalvanized hardware fly screen with open ends, 2 or 3 inches long and about ½ inch in diameter, inserted upright in the soil. Such tubes cost \$2.25 per thousand in 1936; installation and sowing added \$2.00.

and below the germinating surface, were investigated in Mississippi by Gemmer and others (201). In one experiment 1,488 seed spots gave the results shown in Table 16. These data indicate that seeds are subject in varying degree to the depredations of birds and rodents on different seedbeds. Blackbirds, mourning doves, southern meadowlarks, and quail were chiefly responsible for the loss of seed when December frosts sharply reduced insect rations. Mice and squirrels were of secondary concern. In unprotected and mulched spots, all seeds sown in January were lost. The three methods of sowing which afforded some protection gave better results than the unprotected surface sowing in autumn. In winter, when food for birds and rodents is scarce, seed sown in wire tubes did very well (80 percent germination), and those in drills fairly well (28 percent germination) while sowings on unprotected surfaces failed completely whether mulched or not.⁸

Survival apparently increased with the degree of protection (natural or artificial) but the effect of cultivation or burning was not so clearly manifest. The advantage of sowing in tubes or drills to protect seeds from predators, and on prepared surfaces to hasten germination, was apparently offset in many instances by damage to seeds or to nearly stemless seedlings as a result of burying with silt.⁹

The effect of artificial mulches on direct seeding is shown in Table 17. Rodents, prone to seek food or shelter under mulch, were not abundant in this instance. The heaviest crop of seedlings was found under heavy hay, followed by the light hay and pine-straw mulches. Mulches seemingly provided partial protection against birds.

⁸Metal screen tubes served their purpose in protecting the seeds from birds, but they were disadvantageous in other ways. Some became filled with enough sand to interfere with germination. Direct insolation may have heated the wires to temperatures high enough to injure any tender seedlings touching them. No evidence of this, however, was noted in the field.

⁹Silting is greatest on cultivated surfaces, intermediate on burns, and least on naturally rough surfaces. Some silting damage may be avoidable through improved methods of sowing.

Table 17.—*Effect of mulch upon germination of longleaf seed and survival of seedlings*¹ (After Gemmer)

Kind of mulch	Milacre quadrats	Mean seedlings per milacre	Standard error of mean
	<i>Number</i>	<i>Number</i>	
Light hay	60	57.5	±2.64
Heavy hay	30	117.6	±8.03
Total or average	90	77.5	±4.37
Pine straw	135	44.3	±1.39
Grand total or average	225	57.6	±2.21

¹One ounce (about 250 seeds) was sown on each milacre quadrat in December 1935 and examined 14 weeks later. No records were made of germination alone, or of loss in the interim.

In artificial seeding the mulch is on top of the seeds, where it belongs, but this is not common under natural conditions.

Under natural conditions, seeds often find it difficult to penetrate the mulch on areas of rough. Gemmer et al (201) observed that the 1-year rough proved to be only a slight barrier to seed, since 46 percent reached mineral soil at the time of sowing, and much of the remainder within 2 weeks. At the time of sowing on the 3-year rough 15 percent of the seed penetrated to mineral soil; in oak brush, 6 percent; and in an old-field stand, 2 percent.

Obviously, high initial penetration of the rough is desirable but not necessary so long as appreciable numbers of seed reach the mineral soil fairly promptly. Records of early survival of seedlings for the same cover types, based on the numbers of seed sown, were as follows: 1-year rough, 1 percent; 3-year rough, 1.2 percent; oak brush, 0.6 percent; and old-field stand, 14.4 percent. The superior catch in the old-field stand is attributed to the relative absence of birds—although seedlings cannot survive unless the overstory trees are removed. If this superior catch is typical of natural as well as old-field stands, it suggests that reproduction might be obtained in advance of final cuttings and extensive logging. In fact, about 40,000 acres were successfully regenerated in this way at Bogalusa, La.

Germination and penetration into mineral soil covered with native vegetal

Table 18.—*Effect of seedbed surfaces on germination and soil penetration of longleaf seed in greenhouse tests*¹ (201)

Seedbed	Germination				Penetration			
	Pine needles	Sedge	Oak leaves	All types litter	Pine needles	Sedge	Oak leaves	All types litter
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Soil covered ½ inch deep with:								
Undecomposed material	2.50	20.85	67.50	30.30	0	4.00	1.23	1.83
Humus	85.85	94.15	95.85	91.95	85.35	93.81	96.52	93.05
Ash	95.00	95.85	95.85	95.55	51.75	53.04	20.87	41.86
Average	61.10	70.30	86.40	72.60	68.18	66.40	43.73	57.91
Soil uncovered:								
Raw subsoil				85.85				100.0
Topsoil mixed				88.35				100.0
Topsoil burned				85.00				100.0

¹Twenty seeds in each lot were sown on seedbeds in perforated metal flats and watered daily during germination and at intervals of several days thereafter. Ash surfaces were alkaline, pH 8.21, whereas all others were acid, pH about 5. Forest fires typical of the longleaf pine belt seldom leave anywhere near this amount of ash on the surface of the soil.

Table 19.—*Effect of soil density and seed weight on capacity for early establishment of longleaf pine on various soils, as indicated by greenhouse tests*¹ (201)

Behavior and seed-weight classes ²	Soil density ³			Average, all densities
	Loose	Normal	Compact	
SUSQUEHANNA SUBSOIL				
Germination:	Percent	Percent	Percent	Percent
Light	69	67	62	66
Medium	80	71	80	77
Heavy	73	84	61	73
Average, all weights	74	74	68	72
Failure to penetrate:				
Light	27	77	98	66
Medium	31	91	97	72
Heavy	36	74	100	69
Average, all weights	31	80	98	69
Total mortality:				
Light	32	87	98	71
Medium	37	95	99	76
Heavy	38	82	100	72
Average, all weights	36	88	99	73
NORFOLK FINE SANDY-LOAM SURFACE SOIL				
Germination:				
Light	72	60	63	65
Medium	72	81	56	70
Heavy	80	76	59	71
Average, all weights	75	72	59	69
Failure to penetrate:				
Light	31	37	26	31
Medium	25	37	34	32
Heavy	36	38	49	40
Average, all weights	31	37	36	35
Total mortality:				
Light	54	39	28	41
Medium	35	42	34	38
Heavy	40	44	51	45
Average, all weights	43	42	37	41
NORFOLK SAND SURFACE SOIL				
Germination:				
Light	67	69	70	69
Medium	79	81	72	77
Heavy	71	84	81	79
Average, all weights	72	78	74	75
Failure to penetrate:				
Light	32	31	29	30
Medium	27	18	34	26
Heavy	38	39	44	40
Average, all weights	32	29	36	32
Total mortality:				
Light	42	47	32	40
Medium	28	23	35	29
Heavy	41	41	67	50
Average, all weights	36	36	46	40

¹These tests were made in early spring, in open cans, under a glass roof painted white, with maximum temperature of about 100° F. Hence seeds probably were not adversely affected by abnormal germination.

²Seed-weight classes ranged as follows (in milligrams): Light, 61-85; medium, 86-110; and heavy, 111-135.

³Loose soils were sifted, normal soils were maintained in natural structure, and compact soils were mechanically compressed.

Table 19.—*Effect of soil density and seed weight on capacity for early establishment of longleaf pine on various soils, as indicated by greenhouse tests*¹ (201)—Continued

Behavior and seed-weight classes ²	Soil density ³			Average, all densities
	Loose	Normal	Compact	
ALL SOILS				
Germination:				
Light	69	65	65	67
Medium	77	78	69	75
Heavy	75	81	67	74
Average, all weights	74	75	67	72
Failure to penetrate:				
Light	30	48	50	42
Medium	27	47	58	44
Heavy	37	51	62	50
Average, all weights	31	49	57	45
Total mortality:				
Light	43	58	52	51
Medium	34	52	59	48
Heavy	40	56	72	55
Average, all weights	39	55	61	51

materials were tested in the greenhouse by Gemmer. Table 18 indicates that the best germination for longleaf pine was on mineral surfaces. Except for surfaces covered with undecomposed pine needles or broomsedge, 68 to 96 percent of the longleaf seed germinated. Somewhat less success was obtained on surfaces covered with partly decomposed litter. On soils covered with undecomposed litter, there was almost no survival. Slash pine showed a greater tolerance for alkaline conditions and survived better than longleaf on most surfaces covered with partly decomposed litter or ash. On mineral surfaces, however, longleaf has a somewhat better chance of survival.

Further greenhouse tests revealed that germination was generally lowest for the lightest seed on the most compact soils (Table 19). On the whole, however, seed weight was an insignificant factor. Early mortality (i.e., during the first 3 months) was highest on the normal and compact Susquehanna subsoil. Although attempts to increase compaction mechanically had no effect on the behavior of seeds, loosening shortened the penetration period by over a day and increased the number of seedlings on heavy soils. On Norfolk soils, however, loosening the soil brought no appreciable reduction of early mortality. Once the seedling radicles penetrated mineral soil, losses were insignificant during the 3-month period of greenhouse observations.

Seeds need only suitable temperature and moisture to germinate, but seedbed characteristics greatly affect early establishment. To germinate and catch, seeds must have access to the surface of the soil and be protected from injurious agents. Gemmer et al (201) provided equal exposure to natural seed fall on three seedbeds in southern Mississippi under the following treatments: broadcast burned, cultivated by spading, and undisturbed 3-year rough. Of the seeds germinating from the excellent seed fall of 1935, 53 percent were in the rough, 30 percent on cultivated soil, and 17 percent on burned surfaces. A year later surviving seedlings totaled 7,500 per acre on the rough, 3,500 on the cultivated, and 2,080 on burned plots. On small unprotected plots where predators are permitted to concentrate, complete ex-

posure of mineral soil or cultivation of hard soil is of no avail. On larger tracts, seeds can be given moderate protection on mineral surfaces in a 1-year rough.

SEEDLING DEVELOPMENT

Normal Seedlings

Three stages of normal seedling development are shown in Figure 21. Note that the grass stage *B* represents a progression of stemless trees. The terminal buds of normal seedlings are firm, stout, sharp-pointed, scaly-white, and candlelike (Pls. 4 and 14). The approximate development of normal seedlings is as follows:

	Range Years	Average Years	Seed fall to end of stage Years
1. <i>Defenseless cotyledon stage</i>			
a. Emergence from seed	}-----	$\frac{1}{2}$	$\frac{1}{2}$
b. Seed leaves free			
c. Formation of primary needles			
2. <i>Resistant grass stage</i> -----	2-9 $\frac{1}{2}$	6	2 $\frac{1}{2}$ -10
3. <i>Hardy growing stage</i> -----	2-3	2 $\frac{1}{2}$	4 $\frac{1}{2}$ -13

Strictly speaking, the hardy growing stage ends when seedlings attain sapling size; the upper limit is breast height or 4 $\frac{1}{2}$ feet. In the cotyledon stage seedlings are stemless; in the resistant grass stage, stems thicken slowly; and in the hardy growing stage, stems elongate rapidly. Outside of nurseries, seedlings rarely develop faster than the above figures indicate.¹⁰

In the grass stage, longleaf seedlings are fairly resistant to adverse conditions, but inadequate moisture, vegetative competition, and injurious agents may combine to make their existence precarious. Inadequate moisture may be caused by insufficient rainfall, low retentive capacity of soils, high degree of exposure to sun and wind, rapid transpiration of seedlings, or insufficient root penetration. Growing space must be contested with associated seedlings, grass, weeds, sprouting shrubs, and trees. The main injurious agents, in addition to adverse weather, are fire, disease, insects, domestic and wild animals, and the smothering effects of dead grass and litter. Seedlings are most often killed by several forces acting simultaneously.

After emerging from the grass, the seedlings are susceptible for a brief period to injuries from climatic, pyric, or biotic causes, although they are better established than in the grass stage and less dependent on favorable moisture and fertility and consistency of soil. Developing with sudden speed, they then outgrow all vegetative competitors at the grass level.

¹⁰An example of extraordinary natural development was recorded in Grant Parish, La., in 1937, where 16 seedlings were growing in a spot where, 2 years before, a rotten snag had fallen and been entirely consumed by fire. The fire not only killed all competing vegetation but deposited a large amount of mineral nutrients. Competing vegetation did not reappear abundantly until the 1938 growing season, when the longleaf seedlings averaged 1.1 inches in diameter and were nearly 8 inches tall. Brown spot affected 17 percent of the foliage. Four seedlings started height growth by the middle of their second season from seed, and the others were on the verge of active height growth in their fourth year. By contrast, other seedlings in the nearby rough averaged 0.53 inch in diameter and 0.1 foot high in their fourth year—only half the requisite size for a spurt in height growth. Bickford, C. A. Some unusual longleaf pine seedlings. 1939. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

Seedlings coming in naturally at Urania, La., in 1913, beyond a 30-foot radius of competing larger trees, and free from brown spot, began height growth in their sixth year and developed normally into saplings (113).

SEEDS, SEEDBEDS, AND SEEDLINGS

87

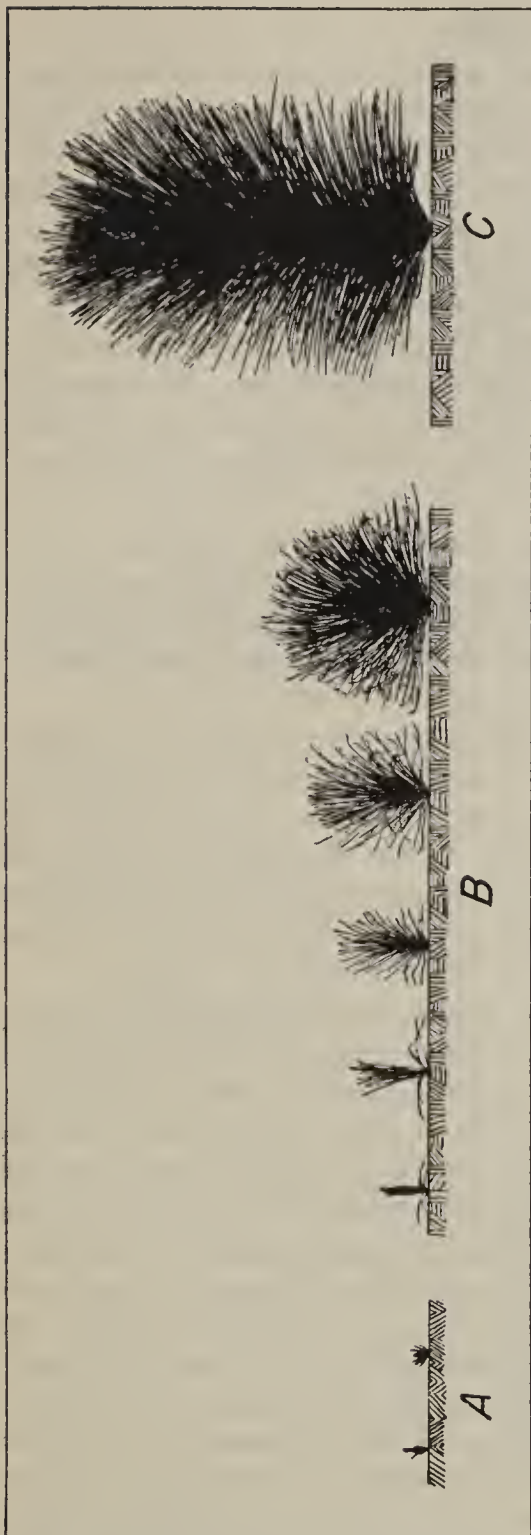


Figure 21.—The principal stages through which longleaf seedlings pass: A, brief and defenseless cotyledon stage following germination; B, resistant grass stage, including the period of slow top growth (height of stem usually less than 4 inches and diameter always less than 1 inch), during which the root system expands and the stem slowly thickens; and C, the hardy growing stage, characterized by regular and rapid height growth.

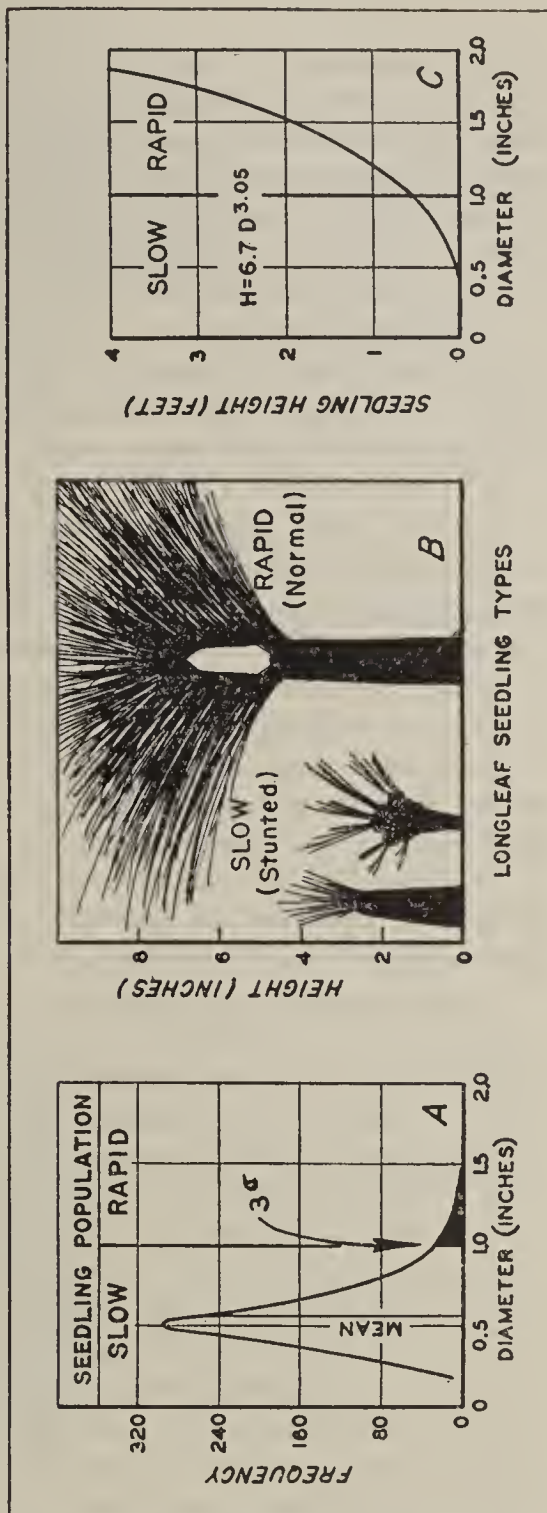


Figure 22.—Diameter distribution, characteristic appearance, and stem proportion of longleaf pine seedlings: A, distribution of seedlings in a dense stand by diameter at ground line (the ultimate stand will come from rapid-growing seedlings which succeed in attaining one inch in diameter); B, silhouettes of stunted and normal seedlings; and C, ratio between height and diameter of seedlings shown in A.

Stunted Seedlings

The cotyledons or seed leaves of stunted seedlings are somewhat more bluish than most associated grasses, as are also the weak primary foliage and to a lesser extent the semijuvénile pairs of fascicled needles¹¹ (Pl. 15). Even the most vigorous seedlings in nursery or field pass through a stage in which their primary needles are bluish, but the 2-needle, green-foliage stage soon follows. Prolongation of the primary-needle stage, or retrogression to it, as well as prolonged absence of a strong and sharp-pointed terminal bud, are symptoms of abnormality.

Secondary foliage in normal 3-needle bundles is grass-green while young, resembling the new blades of narrow-leaved grass like *Andropogon tener*. The leaves of puny stemless longleaf pine seedlings may be distinguished from grass by their triangular cross section and resinous taste. Immature grass resembles an angle-iron in cross section and is nonresinous.

In view of the above conditions, it is not surprising that the prospects of successful longleaf reproduction are often underrated because of failure to note the presence of normal seedlings, or to judge correctly the recuperative capacity of stunted plants. This explains why apparently denuded longleaf forests have unexpectedly sprung into productivity after 10 or 20 years.

Stunted seedlings at first resemble the normal ones (Fig. 21, B), the condition being arrested progress without distinctive form, but if growth is delayed for several years by repeated defoliation from brown spot, fire, or other causes, the plants acquire an abnormal appearance (Fig. 22, B, two specimens to the left, and Pl. 15, C and D). The conical form (Fig. 22, B) indicates weak and failing terminal growth; the top-heavy and gnarled stem shows effects of repeated terminal injury. Stunted specimens lack the white sharp-pointed bud.

Height growth of seedlings is slow at first (whether healthy or diseased or otherwise injured) and much more rapid later. If stunted seedlings enter the cylindrical white-bud stage, they emerge rapidly from the grass. Usually, early stunting from which seedlings are later released has no effect on ultimate survival. However, gnarled growth of wood, resulting from severe damage by sheep or goats, may kill vigorous saplings because conductive tissue has been strangled in the swollen bases.

Usually, the height-diameter relation of longleaf seedlings takes the form of a J-shaped curve (Fig. 22, C), which becomes a straight line if plotted on logarithmic paper. Sometimes only a few seedlings in a stand start active height growth. In one instance, where several thousand per acre remained 10 to 15 years in the grass (Fig. 22, A), the slow-growing majority perished. Regardless of age, rapid height growth does not start until the seedlings are at least 1 inch in diameter at the ground line. This is the simplest criterion for detecting impending active height growth. During the later grass stage, healthy specimens grow from 1 to 2 inches in height annually, and diseased specimens 0.3 to 0.9 inches. In the active growing stage, healthy seedlings grow 1 to 3 feet in height per year; diseased individuals, about 0.1 to 0.3 feet.

¹¹Ellison, Lincoln. Notes on the occurrence of diphylloidy in longleaf pine seedlings. 1933. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

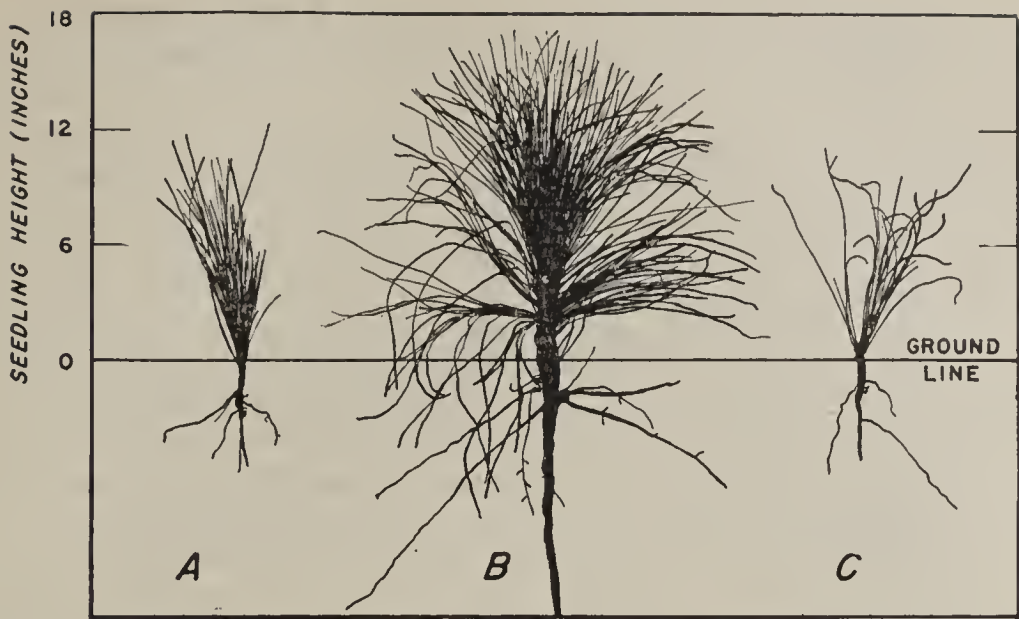


Figure 23.—*A*, 9-year-old longleaf seedlings typical of an area annually burned; *B*, undiseased and unscorched; and *C*, badly infected with brown spot. Note that *B* has attained the vigor necessary for emergence from the grass. *A* and *C* will probably not survive.

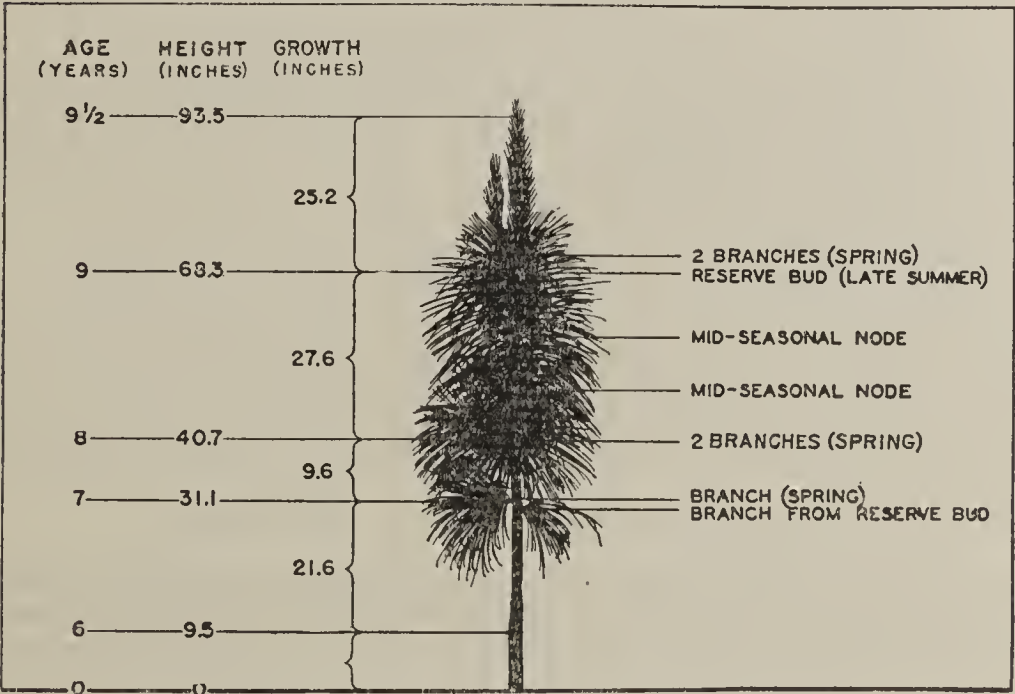


Figure 24.—Typical development of a longleaf sapling unscorched for at least 4 years. Assuming that 6 years were required to grow the first 9.5 inches, the tree reached nearly 8 feet in 9 1/2 years. (After W. R. Mattoon)

LONGLEAF PINE

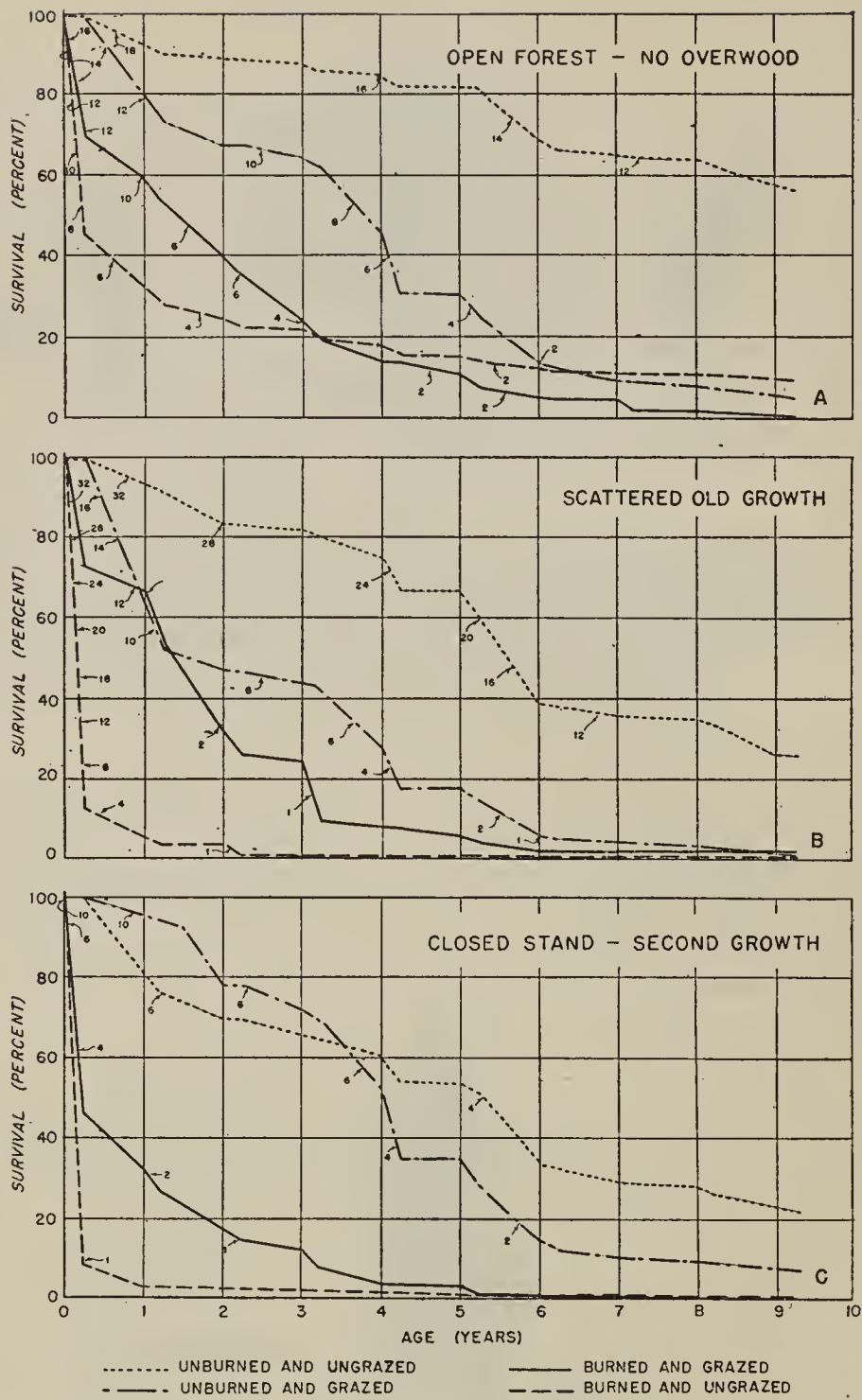


Figure 25.—Effect of annual burning and grazing of cut-over forest land on the survival of longleaf seedlings in the grass stage. A, open stand—no overwood; B, scattered old growth, about 10 trees per acre; and C, stands of second growth with crown canopies closed and approaching full stocking. Numbers before arrows indicate current stands of seedlings in thousands per acre.

Considerable stem development, as shown in Figure 23, *B*, is necessary before active height growth starts. The normal sapling stage that follows is shown in Figure 24.

If severely defoliated by frequent scorching or, in the absence of fire, heavily infected with brown spot, stunted seedlings lose their needles in the second year. In some stands the lack of second-year foliage interferes with photosynthesis to such an extent that normal development and height growth are impossible; all seedlings remain stunted (587) and attain diameters of as little as half an inch at 10 years. These generally do not emerge from the grass at all.

The effect of overwood in reducing the survival of seedlings is shown in Figure 25. Note that the stands in *B* and *C* contained fewer seedlings than did stands under comparable land treatments shown in *A*. It is apparent from these curves that there were distinct differences in survival rate by the end of the first and second years, owing to effects of the four combinations of annual burning and grazing. These significant differences were temporary, however, because none of the land treatments used in the tests proved suitable for longleaf pine. Hence the regeneration failed for all treatments. No seedlings emerged from the grass within 10 years, when less than half the size needed for active height growth was attained.

Knowledge of the peculiarities of seedlings is useful in the management of longleaf forests. If the causes of stunting or injury are correctly diagnosed in time, seedlings can be helped to make rapid height growth, perhaps by a burning treatment to control disease, or fencing to keep out hogs. On the other hand, failure to diagnose the situation correctly, and in time, often leads to unnecessary expense for planting, or to damage from burning or hog grazing.

Mineral and Moisture Requirements

Under natural conditions, longleaf seedlings must share available minerals and moisture with competing vegetation. Whether competition for moisture is more important than for mineral nutrients has not been definitely determined.¹² Pessin's laboratory tests in prepared solutions indicate that the nutrient requirements are not high. He found (443)¹³ that "the poorest growth and the lowest dry weight occurred in the solutions lacking potassium and iron. The best growth and the greatest dry weight occurred in the full nutrient solution and in the solution lacking phosphorus. Mycorrhiza were most numerous on the most vigorous seedlings." These results are shown in Table 20. Although seedlings growing in solutions lacking phosphorus and sulphur were not quite as vigorous as those in the full nutrient solution, apparently longleaf does not require much of these elements; indeed, under natural conditions, the species thrives on soils notably poor in phosphorus. Seedlings

¹²Pessin (447) found that in greenhouse containers seedlings surrounded by unburned grass were backward, but in the midst of burned grass they did almost as well as in similar containers without competition. Pessin tentatively concluded that the competition was principally for mineral nutrients, but the evidence was not convincing, as no information was available on soil moisture or the effect of burning the grass on rates of transpiration.

¹³Each of 8 nutrient conditions was tested by growing 6 longleaf seedlings for 222 days in the greenhouse. At the end of this period the seedlings were removed from the jars, and the tops and roots were measured; they were then oven-dried and weighed. Because the product of greenhouse water cultures may be abnormal in unsuspected ways, and seedlings in this experiment were not subjected to field-survival tests, the results are suggestive rather than conclusive.

Table 20.—Average development of longleaf seedlings in nutrient solutions¹ (443)

Element omitted	Dry weight				Root system		Foliage		Survival	Acid reaction of solution
	Root	Top	Total	Ratio top:root	Length	Laterals	Length of needles	Fascicles of needles		
	Grams	Grams	Grams	Grams	Centi-meters	Number	Centi-meters	Number	Percent	pH
None	0.559	1.421	1.980	2.6:1	13.7	35	27.4	13	100	5.73
P	.466	1.050	1.516	2.3:1	20.3	25	19.6	10	100	6.14
Ca	.305	1.020	1.325	3.3:1	21.1	19	23.1	7	67	6.14
S	.290	.816	1.106	2.8:1	16.3	15	21.3	7	100	6.21
N	.426	.562	.988	1.3:1	35.6	23	18.3	5	100	5.45
Mg	.147	.647	.794	4.4:1	24.1	14	21.1	7	83	6.06
K	.181	.546	.727	3.0:1	22.9	17	11.9	4	50	5.98
Fe	.117	.396	.513	3.4:1	13.2	10	16.8	4	83	6.28

¹The full nutrient solution contained:

Ca	Calcium	132	parts per million	Mg	Magnesium	43	parts per million
N	Nitrogen	421	do.	S	Sulphur	159	do.
K	Potassium	141	do.	Fe	Iron		trace
P	Phosphorus	140	do.				

growing in solutions lacking nitrogen and calcium were somewhat less thrifty than those supplied with all the mineral elements, but here again it is evident that the need for calcium and nitrogen is not great, since these are not abundant in soils inhabited by thrifty longleaf.

Once established, longleaf seedlings require relatively little moisture, but moisture deficiency is apt to keep seedlings in the grass over long periods. Availability of moisture depends, among other things, on location relative to the roots that seek it. In one experiment, the soil moisture under a 12-year rough was compared with that in adjacent plots on which the entire herbaceous cover and litter had been removed. During a dry autumn (September to November) the denuded plots were somewhat drier in the top 2 inches of soil than the grassy plots—moisture averaging 4.2 instead of 5.3 percent of dry weight—owing to increased evaporation in the absence of a grass mulch. The grassy plots were drier in the deeper 6 to 12 inches of soil—moisture averaging 5.9 instead of 7.6 percent of dry weight—because of transpiration by the grass. In the grass stage, seedlings compete with grass roots in their zone and with each other's roots at all soil levels.

Longleaf is most sensitive to the amount and distribution of rainfall during its germination period. Prompt germination is desirable because it shortens exposure to seed-destroying agents. In a greenhouse test an equivalent of 3.6 inches of rainfall brought the most energetic germination when applied at the rate of 1.2 inches or more at a time (Table 21). The application of moderate amounts at 4- to 9-day intervals resulted in less prompt germination than from lighter or heavier applications of water. The effect of the heavier applications in the soaking of seeds may have stimulated them, since moisture content at the start is probably the controlling factor.¹⁴

¹⁴Although the seeds in these tests displayed appreciable differences in germinative energy, they were much alike and nearly perfect in germinative capacity. Fresh from the cones following extraction by hand, these seeds germinated 100 percent, or nearly so. Such uniform quality cannot be expected from commercial seed lots.

Table 21.—*Effect of watering on germinative energy of longleaf seeds in greenhouse flats*¹ (201)

Amount of water (inches)	Number of times applied	Interval of application	Percent of seeds germinated within 10 days
0.1	36	Each of 36 days	48 to 76
.2	18	Every other day	
.3	12	Every 3d day	
.4	9	Every 4th day	20 to 38
.6	6	Every 6th day	
.9	4	Every 9th day	
1.2	3	Every 12th day	70 to 80 ²
1.8	2	Every 18th day	
3.6	1	First day only	

¹An equal amount of water, the equivalent of 3.6 inches of rainfall, was supplied in each of 9 tests. Over a period of 36 days relatively large amounts, applied at long intervals, were balanced in other tests by smaller amounts applied at correspondingly frequent intervals.

²80 to 100 percent before second watering.

Adequate moisture is required not only for germination but also when seedlings are becoming established. In tests conducted by Pessin (444), longleaf seedlings, like those of slash pine, absorbed most water, transpired most, and developed best in soil which had abundant moisture but was not completely saturated. In these tests slash pine endured a wider range of moisture conditions than did longleaf, but the best conditions for growth were apparently within the same limits for both species. Longleaf seedlings tolerated dry soil somewhat better than did slash, while the latter apparently were more tolerant of extreme wetness. Similarly, though seedlings of both species survived well under extremely dry and extremely wet conditions, slash had slightly higher mortality in very dry soil and lower mortality in wet soil. In moist soil many mycorrhiza were formed in longleaf, and seedlings bearing mycorrhiza were particularly vigorous. Neither species did well in wet soil, thus accounting perhaps for the absence of longleaf on poorly drained grassy forest sites or savannas.

With moisture above 15 percent of the dry weight of the soil, longleaf seedlings in the greenhouse had heavier and longer taproots than did slash, and required less soil moisture to build a unit of dry matter (Fig. 26). Whether this superior efficiency is true for larger trees is not known.¹⁵ Its relatively long and deep roots are a distinct advantage to longleaf, not only on dry sites but during arid years on good sites.

At the Stuart Forest Nursery in central Louisiana it was found that the best growing conditions for longleaf require supplementary watering. Altogether, at least 1 inch of water weekly was needed.¹⁶

Root Systems

Most of the root studies of longleaf pine have been made on Florida sands relatively easily removed from fibrous roots. Possibly the root forms typical of longleaf can develop unhampered in such an easily penetrated medium, but the more prevalent forms in the heavier clay subsoils of the better longleaf lands may be somewhat different. The findings described in this section must therefore be considered as tentative.

¹⁵Even so, for timber growing on the drier sites most typical of longleaf, no practical advantage is seen because in soils with less than 15 percent moisture, significant differences in water-using efficiency of seedlings were not noted. On wet sites, of course, nothing is gained by efficiency in water use.

¹⁶Muntz, H. H. A study of various combinations of sprinkler watering and cultivation. 1940. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

LONGLEAF PINE

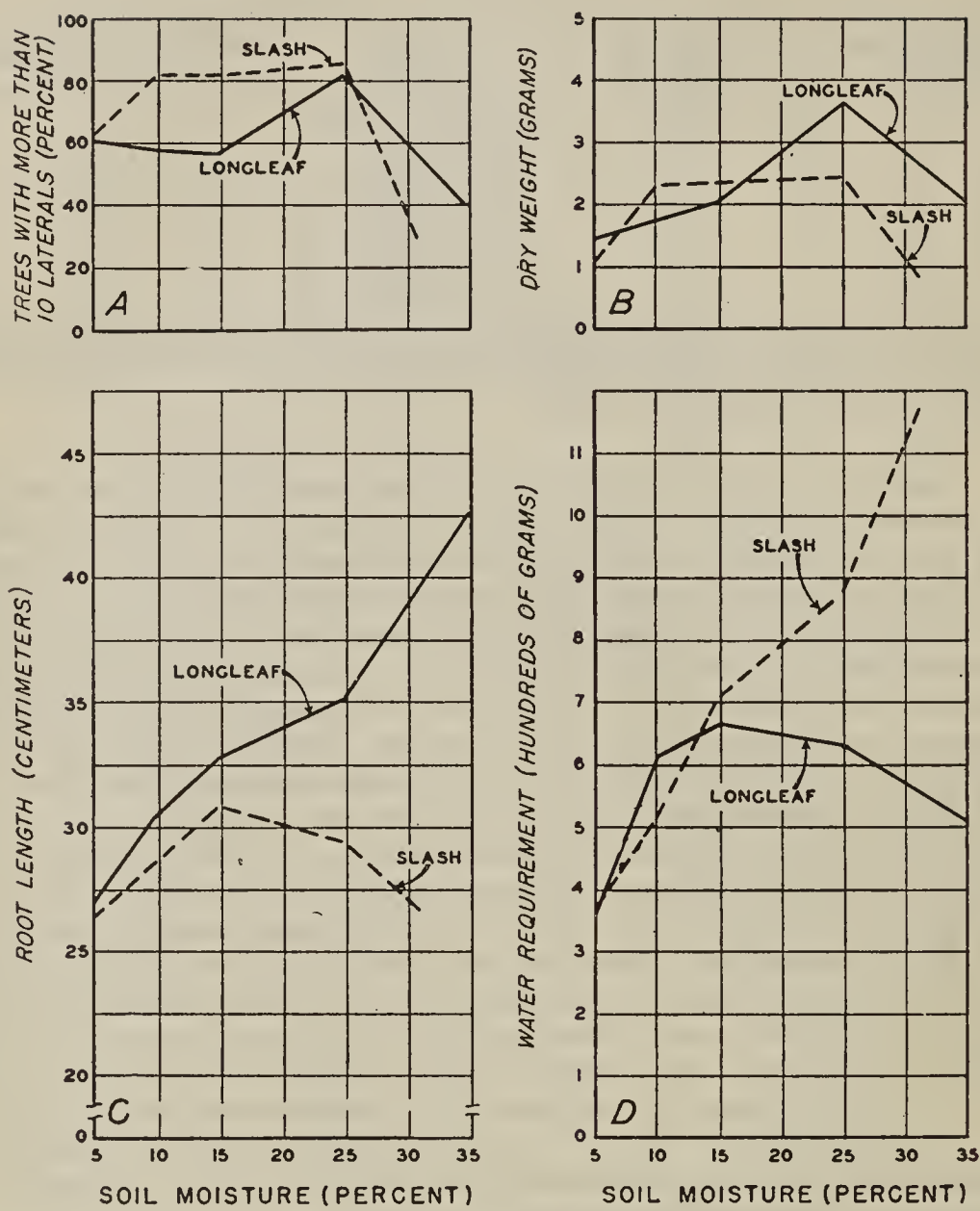


Figure 26.—Comparison of first-year development of longleaf and slash pine seedlings in relation to soil moisture. A, more abundant lateral roots on slash than on longleaf in the drier soil; B, longleaf heavier than slash pine in moist soil; C, longleaf roots longer than those of slash. D indicates the amount of water required to produce one gram of dry plant substance (444).

Longleaf roots thrive on unfavorable sites and also respond with rapid growth on loose, loamy, well-drained soils. In the first few years seedlings spend most of their energy in developing stout, spindle-shaped taproots much longer than the stem. At the collar, the root is nearly as thick as the stem, though a definite constriction may separate the stem from the root. Below the collar, the root tapers off. Thickness varies with site condition and age. During the grass stage, horizontal extensions are superficial, the feeding roots being concentrated in the same zone as those of the

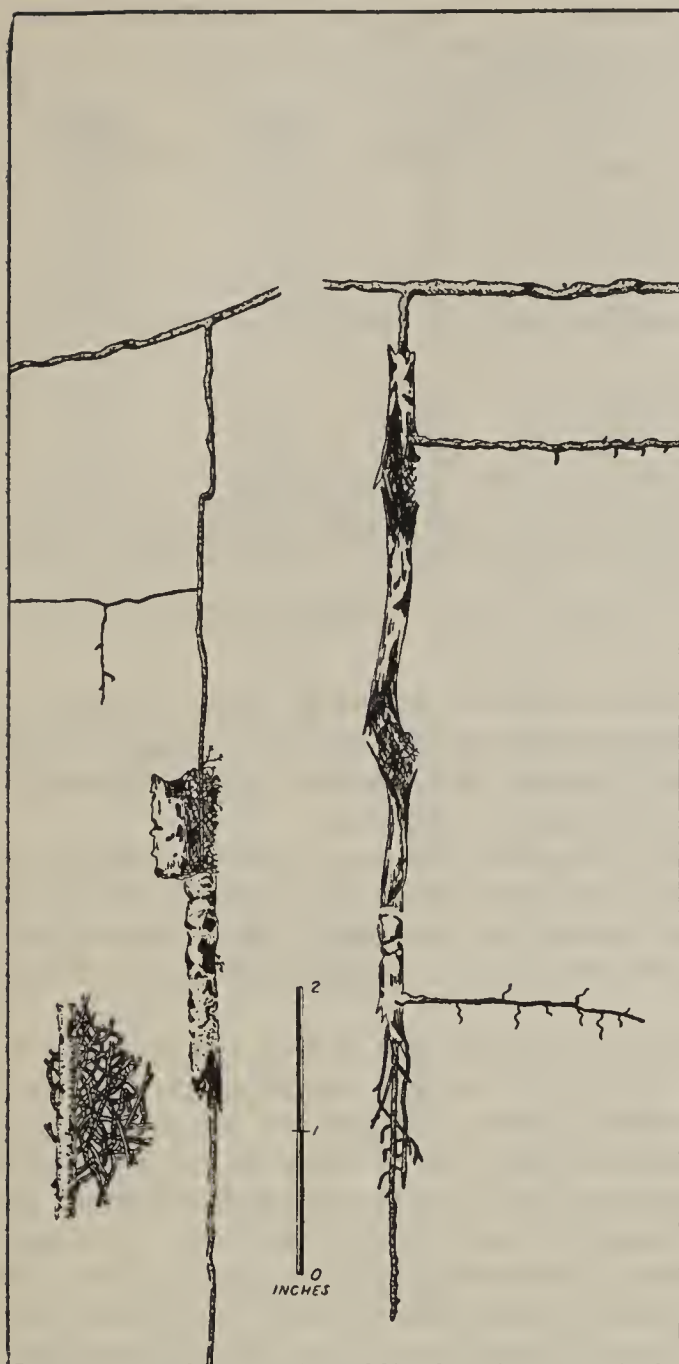


Figure 27.—Longleaf pine roots growing within decayed roots of other vegetation.

grasses. In seedlings which have started active height growth, there are horizontal roots at lower depths.

Penetration of roots has been frequently observed in greenhouse tests. Some specimens make phenomenal growth, such as 21 inches in 15 days after seeding. In one instance yearling (1-0) nursery stock, root-pruned to 8 inches at the time of planting, penetrated 30 to 40 inches of sandy soil in 3 months.

Development of roots on some 400 longleaf seedlings grown during 5 months in both wet and dry sand and clay soil cultures led to the conclusion that while taproot penetration was greatest in the drier sand, the typical form of the root system was not affected by moisture or soil texture. The lateral roots, however, which are comparatively short and unbranched, showed a tendency toward greater length in wetter soil (340). One nursery seedling is reported to have penetrated 8 feet deep in 10 or 11 months. Of course, the average rate of root development is much less (Fig. 38).

The average maximum devel-

opment noted was $5\frac{1}{2}$ inches in about 3 weeks between the 80th and 100th day, and 24 inches in the first 120 days.

Minimum rates consistent with continued existence were not recorded, but field observations on 13-year-old seedlings in the grass stage, spaced 24,000 and 185,000 per acre, showed that extreme density had adverse effects on both laterals and taproots.

As Table 22 indicates, longleaf seedlings in heavy stands are thoroughly and deeply rooted in their initial stage (441). In all stands, especially the denser ones,

Table 22.—*Effects of density on average root development of disease-stunted 13-year-old longleaf seedlings naturally seeded on Ruston fine sandy loam, Bogalusa, La. (441)*

Height class (inches)	Basis: seedlings	Lateral roots		Total length	Taproot length
		Frequency	Depth of occurrence		
	Number	Number	Feet	Feet	Feet
Very dense stand: ¹					
1	10	22	0.6	3.9	2.1
2	7	28	.7	5.2	2.5
3	2	37	1.3	13.3	2.3
Average	---	26	.7	5.4	2.3
Moderately dense stand: ²					
1	5	22	0.7	3.8	2.4
2	13	30	1.5	8.0	2.7
3	1	59	.3	11.2	2.2
4	2	45	1.3	9.3	5.0
Average	---	31	1.0	7.3	2.8

¹The very dense stand had 185 seedlings per milacre averaging 1.5 inches high and 0.5 inch in diameter. Generally speaking, these dimensions must be doubled before conspicuous height growth can start.

²The moderately dense stand had 24 seedlings per milacre averaging 2.0 inches high and 0.6 inch diameter at the ground.

the tendency of roots to grow away from those of neighboring plants results in unsymmetrical development. Furthermore, obstacles like stiff clay and undecomposed roots, or easy passages like old root holes and charcoal pockets, affect the location of roots and sometimes produce unusual formations (Fig. 27).

During droughts the taproot of longleaf pines must penetrate relatively dry layers to reach the deeper supplies of moisture. Survival may depend on reaching this depth before extensive surface-feeding roots are formed. In this respect, longleaf seedlings have an advantage over those of other southern pines because of rapid initial root penetration.

The development of roots on taller seedlings, most of them not far beyond the grass stage, was studied by Heyward (279) in the deep Norfolk sands of the Choctawhatchee National Forest in western Florida. This uniform soil interferes very little with inherent root habits. Here seedlings 3 to 30 inches tall had a prominent taproot, from 9 to 12 primary laterals at least 2 feet long originating from the taproot, a number of shorter and secondary laterals, and vertical roots or "sinkers" descending from the primary laterals. The vertical taproots ranged from 34 to 108 inches long, averaging about 60 inches, and penetrated 36 to 72 inches on well-drained, and 22 to 29 inches on poorly drained sites (where the high water-table apparently checked their growth). Taproots of 5 or 6 feet were considered normal in this study, although one seedling, only 13 inches high, had a 9-foot root. All specimens within an 8-foot radius had vertical roots or sinkers, some of which penetrated as far as the taproot and had as many sublaterals (Fig. 28).

As a rule, the laterals radiated to about 15 feet in nearly straight lines, although curved courses and changes in direction were common. In vertical sectional views, the laterals extended at a uniform depth throughout their length. Thus, the root system of longleaf seems to follow rectangular coordinates, as seen in Figure 29. Of the excavated laterals over 2 feet long, 89 percent were in the first foot of soil; below this level sublaterals under 2 feet long were quite abundant.



Figure 28.—Two types of vertical branch roots or "sinkers" of longleaf pine; at left, with few feeding rootlets, and at right, with many such rootlets. (After Heyward)

On Ruston fine sandy loam in Louisiana, roots of longleaf seedlings stunted by disease and crowding showed little or no growth during mid-winter or midsummer, but rapid growth in spring and autumn. With normal rainfall, pine seedlings and associated plants obtain sufficient moisture; but during drought the grasses, owing to their larger transpiring surface, consume considerable moisture which would otherwise go to the pines. Thus grass competition retards longleaf root development, and this in turn may delay the start of height growth. On the other hand, when seedling development is not delayed, as in nurseries, plantations, and some natural stands of reproduction, roots of first-year seedlings grow actively in winter (Fig. 38).

Once out of the grass, seedlings quickly become saplings (Pl. 16). In this stage the stocky taproot may be over 5 feet long, with a system of laterals 1 to 3 feet below the surface and covering an area of about 150 square feet.

The feeding rootlets are ramified near the tips, owing to the mycorrhizal fungi—clublike or coralline—which form a thin mantle. The mycorrhiza is started when a weft of hyphae envelops a young root tip which may then branch repeatedly (Fig. 30).¹⁷

SUMMARY

Longleaf pine pollen is disseminated by wind, mainly in March. About 19 months later, the cones release their seeds. Thrifty, open-grown trees begin to bear seed at 20 to 30 years of age, and increase in fruitfulness with increased diameter and unrestricted development of crowns and roots. Heavy seeding often takes place about once in 7 years but frequently at other intervals. Locally, seeding is so irregular that a heavy crop for any particular region cannot be expected at fixed intervals. Complete regional failures in any year, however, are rare.

Satisfactory seed trees are best selected on the basis of productivity as judged by the abundance of cones borne in previous years. Even on reasonably well-prepared

¹⁷In most cases, mycorrhiza are confined to lateral roots close to the ground surface. They average 2.5 mm. in length and 0.7 mm. in diameter, ranging in color from buff when young to light brown when mature. They are abundant and distinctly ectotrophic, no penetration of the fungus into the cells being manifest. The fungus is regarded as a beneficial symbiont, not a parasite (434).

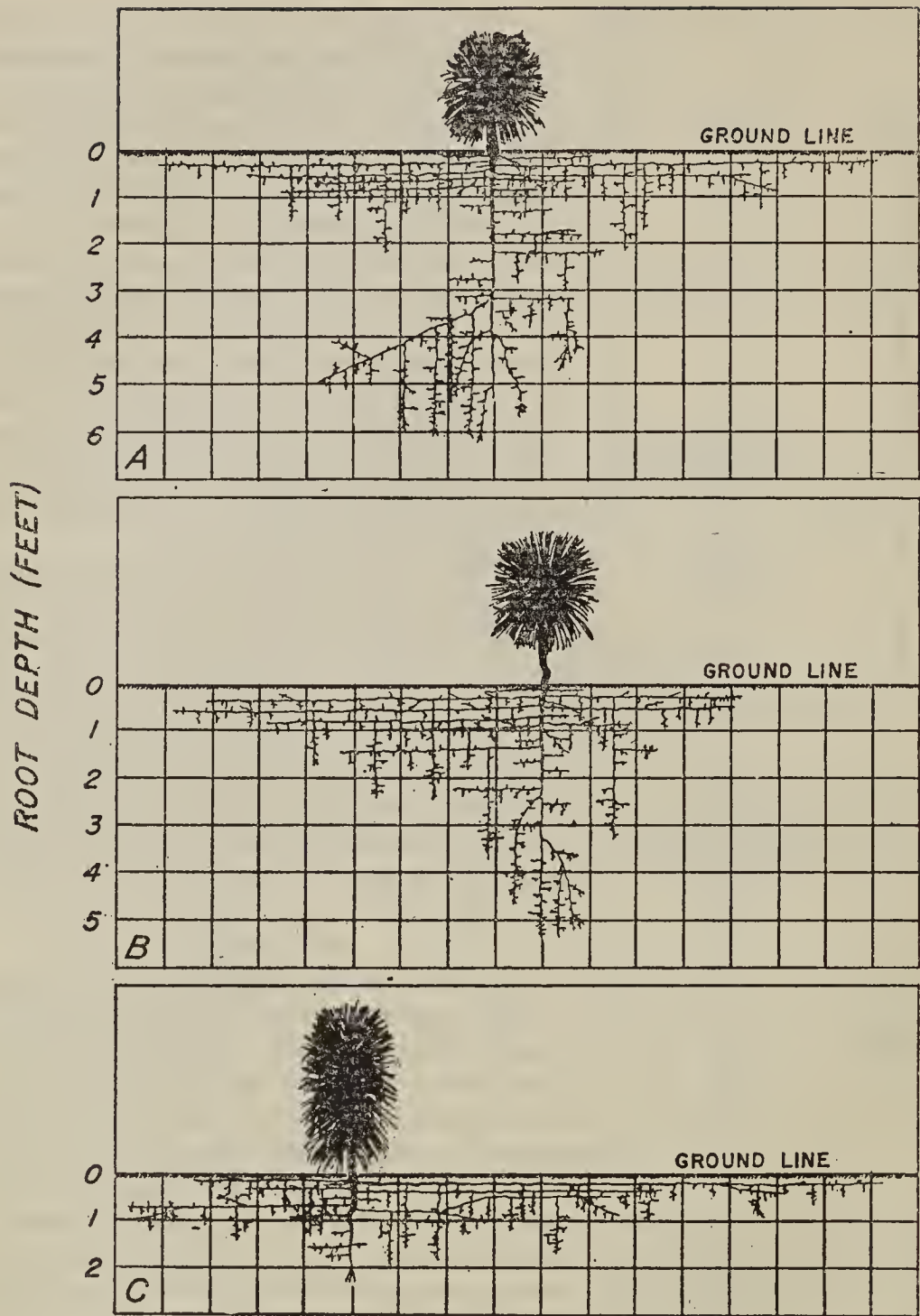


Figure 29.—Seedling root systems typical of longleaf pines excavated from the deep sands of the Choctawhatchee National Forest, Fla. A, from an old field; B, from the longleaf pine-turkey oak type; and C, from a poorly drained site. Note the decreasing depth of root penetration, and the tendency of principal roots to avoid oblique growth in favor of horizontal or vertical positions.

and protected sites, at least 4 trees 14 inches d.b.h. or larger per acre, or 6 trees between 10 and 13 inches d.b.h., should be left as seeders. A tree may be expected to disseminate seed a distance of not more than $1\frac{1}{2}$ times its height. Seed trees, how-

ever, function with certainty only if seedbeds are suitable, predators scarce, stand conditions favorable, and subsequent treatments appropriate.

Attempts at natural regeneration of longleaf pine have rarely been wholly successful. Often seedlings fail to come in naturally, develop abnormally, or die in the grass.

Failures on unburned cut-over lands with adequate seed trees may frequently be ascribed to the thickening rough of weeds and grass. The catch of pine seeds tends to be best on relatively bare mineral soil protected from seed-eating birds and rodents. If the soil covering is too thin, marauders readily find the seeds; if too thick, mechanical interception prevents germination. A light herbaceous cover, such as a 1-year rough, provides negligible interference and moderate protection for self-sown seeds. A properly timed burning treatment is the most economic means of effective preparation of seedbeds.

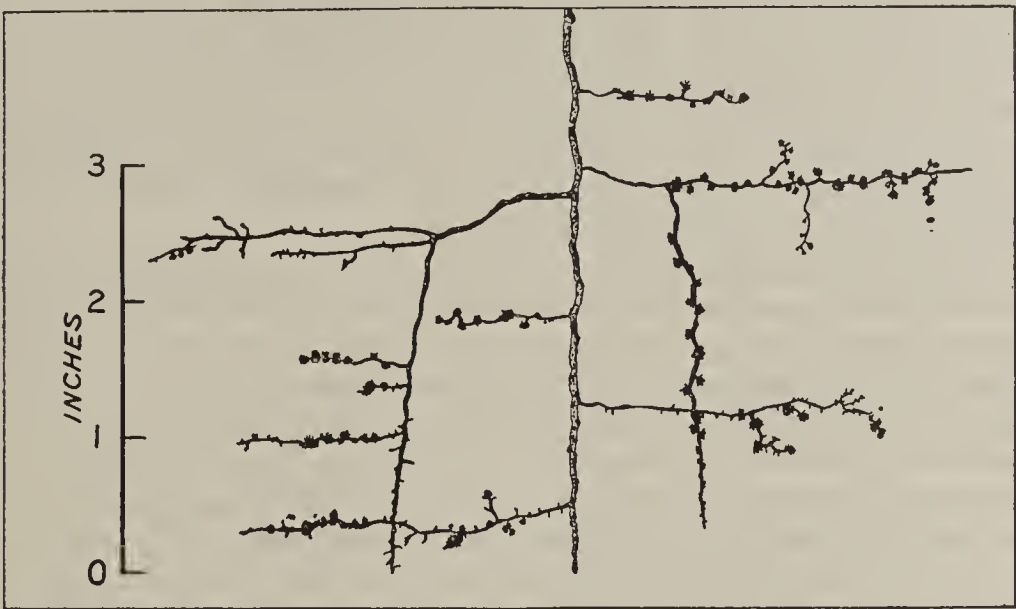


Figure 30.—Longleaf roots with coralline and crustaceous mycorrhiza. (After Heyward)

Normal seedlings remain in the defenseless cotyledon stage for about 6 months but may linger 2 to 10 years in the resistant grass stage; thereafter they stay 2 to 3 years in the hardy growing stage before reaching breast height. Slower progress than this indicates serious stunting, which may result from poor soil, vegetative competition, or injury by fire, animals, or disease. Many backward seedlings become deformed, have abnormal buds and scant foliage, and yet cling persistently to a feeble existence. The mineral and moisture requirements of longleaf pine are relatively low, but moisture deficiencies may keep seedlings in the grass for long periods. Stunted seedlings are capable of prompt and complete recovery as soon as the causes of retardation are removed, but they never emerge from the grass stage until the roots are ready, or the stems at least one inch thick at ground level.

Longleaf seedlings usually have relatively heavy and long roots. In the active growing stage, about 90 percent of the laterals over 2 feet long are in the surface foot of soil; shorter laterals are more abundant below this depth. Roots tend to spread radially and horizontally, but also support vertical branches that supplement the main taproot in penetrating deeper layers of soil. Initial root penetration precedes top growth, but the normal development of a root system can be sustained only by a thrifty top.

VI.

Problems of Natural Reproduction

DIFFICULTIES OF REPRODUCTION

DELIBERATE regeneration of longleaf pine has been rarely accomplished. In fact, the reproduction of this species has been so irregular and uncertain, and its natural controls so imperfectly understood, that successes and failures have been difficult to explain. Many of the factors governing the ability of the species to reproduce are obscure, and the innumerable ecological influences are so inter-related as to make their interpretation difficult. Only with the comparatively recent recognition of the longleaf pine type as an intermediate, rather than a final stage, in the natural succession of plant communities—a temporary phase or subclimax forest associated with frequent surface fires—has it been possible to correlate the various factors involved in the regeneration of the species.

Frenchmen, attempting to settle in Florida in 1567, reported that the woods were filled with superb pines that never yielded seed (390). Undoubtedly they were referring to longleaf. Early in the 19th century, Michaux pointed out that, although a hundred miles of forest could be covered without finding a single cone during an unfruitful year, the seeds of longleaf pine were sometimes very abundant and voraciously eaten by wild turkeys, squirrels, and swine. In Texas the typical longleaf type, according to Bray (47, 48), was an open forest and it could reproduce in no other kind. He observed that seedlings were so scarce, owing to the recurrence of fire, that they could be ignored in estimating the future supply of longleaf timber. Spots missed by annual grass fires, however, supported many yearling seedlings, and areas unburned for longer periods bore good stands of reproduction. Such observations led to the erroneous conclusion, still prevalent, that the reproduction of longleaf is comparatively easy if fire can be kept out of the forest.

Other observers found that, for example, in Mississippi scrub oaks came in so thickly after logging that they retarded new pine growth, or, on limited areas, prevented it altogether (293, 294). In central Alabama it was noted that satisfactory reproduction of longleaf pine could not be obtained where mature timber had been cut to a diameter limit of 14 inches. Trees of this size or smaller did not bear sufficient seed to establish a future crop. The most prolific seeders were 100 and 175 years old and 16 to 24 inches in diameter (58). In other States, small trees in partial clearings were relied upon for reproduction, but with only indifferent success. Many seedlings, not killed early by fire, died later from hog damage or the effects of an overstory (364).¹

¹The prevailing condition seemed to be that found in Marion County, Miss., when a longleaf pine forest 100 to 300 years old was examined following the heavy seed year of 1913. Advance reproduction was present only in scattered groups whose aggregate area was entirely inadequate to maintain the forest (71, 157).

Examples of both failure and success in the reproduction of longleaf following harvest cuttings have been recorded on small as well as large tracts in various localities. In one instance, seed trees selected at the rate of 6 per acre on one plot and 20 per acre on another within a fenced 200-acre tract in Washington Parish, La., failed completely to reproduce on unburned sites despite good seed crops in 1924, 1927, and later. In 1935, an average of 16 of the 20 trees per acre still remained. They had produced about 23,000 seeds per acre in 6 of the previous 11 years, but only an occasional longleaf seedling was found. Birds probably consumed most of the seeds.

In an enclosure half a mile away, longleaf regeneration was conspicuously successful. Here, nearly all of 15,000 acres had reproduced following clear cutting of 10,000 to 15,000 board feet per acre in the virgin stands. Like the 200-acre tract, this entire area was fenced against grazing animals. The heaviest seedling stands developed on a site burned in September 1920 and logged in October and November of that year, just as the cones were opening and before the seeds had a chance to germinate. Areas logged in the early fall received less seed from overhead trees, while on those cut in the late fall many seedlings must have been destroyed in the cotyledon stage by the skidding of logs. Mature trees, together with repeated burning before 1920, had largely freed this forest from competing vegetation and advanced pine reproduction. Nowhere were the seedlings of the 1920 crop exposed to burning in the cotyledon stage. Consequently, by 1928 a few were emerging from the grass.²

Successful reproduction of longleaf from the 1920 seed crop was also reported elsewhere. For example, up to 20,000 seedlings per acre were obtained under management on one forest, whereas on adjacent land with fewer seed trees the new stand was only about one-fourth as dense.

Longleaf regeneration has been generally unsatisfactory in many places. Scrub oaks, gallberry, and palmetto often form dense stands on cut-over land and retard the development of young pines. In 1935, 35 percent of the longleaf area in northeastern Florida, classed by the Forest Survey as reproduction, was stocked with but 80 to 300 seedlings per acre, and only 30 percent had 900 or more seedlings per acre (318). The survey reported brown-spot needle infection and hog damage to longleaf seedlings on less than 5 percent of the area. About 3 percent of the entire forest showed heavy damage from burning. Admittedly, however, the survey could not discover the full extent of injury or destruction of seedlings by disease, hogs, or fire, because of the perishable nature of the evidence. A survey in late winter or early spring might show serious damage, but by fall the evidence would be partly hidden by heavy grass cover, destroyed by the disintegration of dead seedlings, or obliterated by heavy rains. On the whole, brown spot, hogs, and fire were undoubtedly responsible for much greater destruction of longleaf seedlings than the survey indicated.

There is evidence that longleaf reproduction is also irregular in other States. Along the northern and eastern edges of the longleaf belt, shortleaf and loblolly

²Many who doubted the desirability of burning open-range, cut-over longleaf lands were impressed by the phenomenal success of regeneration on burned areas with hogs excluded, both on the Washington Parish tract and on a smaller tract in La Salle Parish (613). Some of the subtle benefits from fire were becoming manifest.

often restock former longleaf sites. Partly cut stands often have an understory of these two more tolerant species (Pl. 17). Much longleaf reproduction is found in dense groups in openings in older stands. Where longleaf has been cut clear, there are usually few seedlings, owing presumably to insufficient seed trees. Since longleaf seedlings often fail to come in naturally or develop normally, the situation warrants more detailed study.

The principal reasons why longleaf has failed to reproduce well in competition with other species are as follows:

1. Heavy cutting in original stands, especially in the western portion of the range, resulting in insufficient seed trees.
2. Infrequent seeding.
3. Insect infestation of 1-year-old cones, preventing their development to maturity.
4. Heavy seeds that do not fly as far as those of other pines.
5. Large seeds that are attractive to rodents and birds.
6. Large seed wings that often prevent penetration of grass and litter and contact with mineral soil.
7. Prompt germination of seed, resulting in heavy winter loss of seedlings.
8. Destruction of seedlings by hogs, and injury by sheep, goats, and brown spot.
9. Slow initial growth, permitting other vegetation to become dominant.
10. Intolerance of shade, resulting in slow growth and high mortality when suppressed.
11. Exclusion of fire, favoring less fire-resistant competitors.

The continuance of unsatisfactory regeneration in longleaf forests may be attributed largely to lack of management or to unwise management. Indeed, mismanagement has been the rule rather than the exception, due to ignorance of the unique life history of the species and incomplete knowledge of the factors determining the life or death of seedlings and hence the succession of forest types.

DEVELOPMENT ON ADVERSE SITES³

The reasons for failures in regenerating longleaf are often complex and obscure. Studies of the species' response to adverse sites throw some light on this problem.

For over 10 years investigations of longleaf pine development were carried on at the Choctawhatchee National Forest in the longleaf pine-turkey oak type typical of poor, sandy sites in western Florida, southern Alabama, and central Georgia. The Choctawhatchee is submarginal for producing timber and naval stores, except along its drainage lines. The Norfolk sands here are inhospitable to plant life, being in places 60 feet deep, with an excessive rate of drainage and a moisture-holding capacity of only 5 to 8 percent.⁴ The forest area is generally open, with a sparse pine overstory, and is only partially occupied by an understory of scrub oaks. The herbaceous ground cover is sparse and seeds reach mineral soil easily. It is estimated that

³This section is based on studies of the more discouraging regeneration problems where the effects of a favorable climate are largely offset by those of extremely poor soils. Experiments on such sites serve a forester in the same way that sterile sand serves a physiologist engaged in greenhouse tests. The tests and observations are useful in revealing important factors in silviculture, but are not reliable measures of their relative effects on timber growing in more favorable locations.

⁴The soil typically contains 1 percent fine gravel, 35 percent coarse sand, 48 percent medium sand, 12 percent fine sand, and 4 percent very fine sand, silt, or clay.

96.7 percent of the surface has no herbaceous cover; light grass covers 1.8 percent, medium grass 1.3 percent, and heavy grass only 0.2 percent of the area.

From 1860 to 1885, logging operations adjacent to navigable water had "high-graded" the forest. After that about 20 years elapsed before Federal control was undertaken of both turpentine and lumbering operations, and another 20 years elapsed before intensive studies were started by the Forest Service. By then, worthless scrub oaks were crowding out pine seedlings.⁵

Favorable weather conditions were found to be necessary for regeneration on these difficult sites. Requirements for successful production, sprouting, and survival of seed were (1) pollination and fertilization during a wet season, (2) formation of seeds during a rather dry year, and (3) germination and first season's growth during a wet year.

A typical seed tree on an adverse site was found to produce 50 cones during a good year, each containing about 20 sound seeds,⁶ thus yielding 1,000 seeds. Allowing for seeds that fail to germinate and seedlings that die quickly, possibly 15 seedlings—representing only 1.5 percent of the seed crop—were ready to start height growth at 10 years of age.

Such heavy mortality of good seeds in a 6- to 12-year interval between major seed crops explained the failure of pines to fill in the extensive areas available to them. Thus, one survey of the Choctawhatchee revealed an average of 12 to 156 seedlings per acre, actually occupying only 1 to 4 percent of the ground. Furthermore, they were but a few inches tall at 12 years, with scant prospect of emerging from the grass for another 10 or 20 years. This added perhaps 10 percent to the long timber-rotation period—obviously a critical situation from the standpoint of timber management.

Since only about 1.5 percent of the seed crop ultimately produces established seedlings on adverse sites, it is pertinent to inquire, on the basis of the Choctawhatchee study, how many seed trees are needed, in a good seed year, to restock an acre on such sites. If it is assumed that a good seed crop from a typical seed tree yields only 15 established seedlings, and that not over one-third to two-thirds of these are properly spaced, then 250 well-distributed seedlings from one crop would require 25 to 50 trees. Seed trees, however, are seldom so numerous on adverse sites, and even where present offer too much competition to seedlings. Thus ample regeneration cannot be secured, as a rule, from a single seed crop.⁷ The period of natural regeneration must therefore include at least two full seed crops, or one full and several partial crops. This cannot be less than 15 years; 25 years seems more reasonable, in view of the many hazards to seedling survival. Another difficulty lies in keeping seed trees alive during such an extended regeneration period. Mortality of round

⁵A summary of the results is found in a report by E. W. Gemmer. Some of the forest management problems in the longleaf pine-turkey oak type as illustrated by conditions on the Choctawhatchee National Forest in west Florida. 1932. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

⁶On sites of average quality about 50 good seeds are usually obtained per cone.

⁷The system adopted for harvesting timber on the Choctawhatchee was to clear cut, leaving 6 round or 1-face turpentine trees per acre. The inadequacy of existing stands of seed trees was indicated later, when 13 seed trees per acre failed to reproduce pine over a period of 20 years.

trees varied on different parts of the Choctawhatchee Forest, but on the whole was held to a low level, averaging 0.5 percent annually. Turpented trees, being more susceptible to damage by insects, disease, and fire, died at the rate of 3 percent each year. Thus nearly half of the turpented seed trees were lost in a 15-year period.

Since the Choctawhatchee stands had become so open through the combined effect of lightning, insects, drought, turpenting, and logging, it was not necessary to open the stands further for seed production. It seemed better to await satisfactory reproduction and then remove all merchantable trees in one operation.

Influence of Cover and Fire

Some extremely interesting relationships between cover and length of seedling survival were found in the Choctawhatchee study. Given equal rainfall and soil drainage, the rates at which moisture is lost from soils and plants bear directly on seedling welfare. Estimating these rates from the evaporating power of the air, the severity of various sites for longleaf seedlings is shown in Table 23 on the basis of

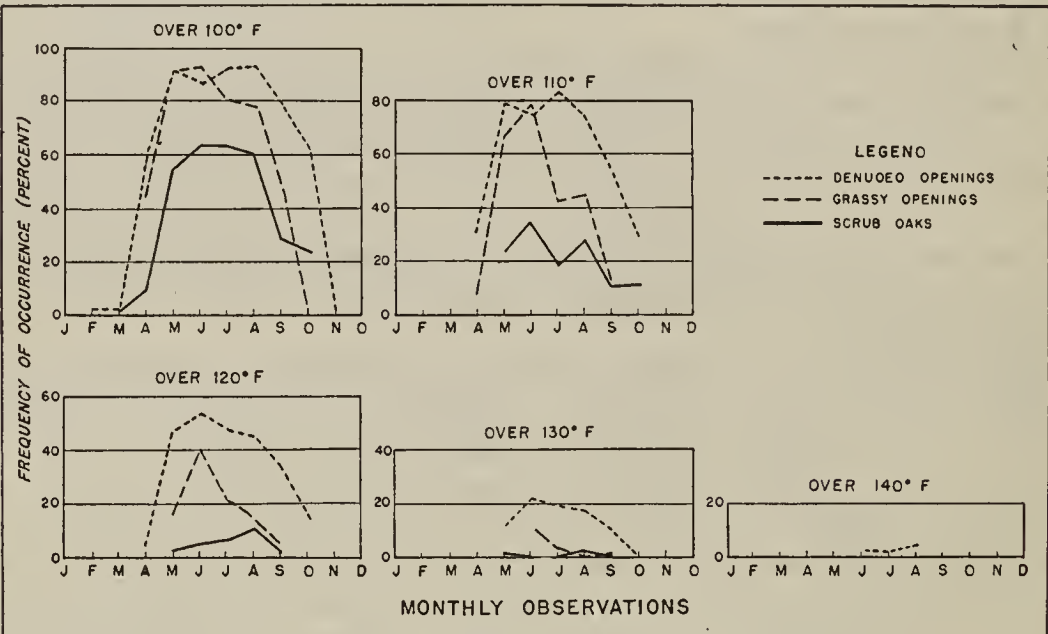


Figure 31.—Frequency of occurrence of high soil temperatures in longleaf pine stands. Note that extreme temperatures occurred less frequently in stands with scrub oaks than with grassy or denuded openings. Choctawhatchee National Forest.

overwood species. The greatest evaporation occurred in the open, next under oak, and least under pine. These differences were more noticeable during the last half than the first half of the growing season.

Vegetative cover on the surface of mineral soil also reduces excessive summer heat. Grass alone is less effective than scrub oak in lowering soil temperatures. Figure 31 shows the frequency of occurrence of extreme temperatures—over 100° F. to over 140° F.—in the region studied. The mean maxima at the soil surface, usually less than 100° F., were reduced by surface vegetation and still more by brush,

Table 23.—Influence of forest cover on daily evaporating power of the air, Choctawhatchee National Forest

Item ¹	Mean volume of water lost in—			Difference in mean evaporation between—			
	Open	Oak	Pine	Open and oak	Open and pine	Oak and pine	Pine denuded and pine undenuded
	cm. ³	cm. ³	cm. ³	cm. ³	cm. ³	cm. ³	cm. ³
White evaporating surface:							
Mean or difference in means	24.1	20.3	16.4	3.8	7.7	3.9	4.0
Standard deviation	±6.7	±5.0	±3.9	±.9	±.8	±.8	±1.6
Black evaporating surface:							
Mean or difference in means	36.5	27.8	23.5	8.7	13.0	4.3	9.1
Standard deviation	±8.0	±6.8	±5.7	±1.0	±1.0	±.9	±1.6

¹Livingston spheroid porous cup atmometers were set at a height of 6 inches above the soil surface. Measurements were confined to a period of 35 weeks between late spring frosts and heavy fall frosts in 1930 and 1931.

Table 24.—Mean annual extremes of soil temperature as affected by denudation and presence of oak brush on the Choctawhatchee National Forest¹

Vegetative cover	Surface maximum		Maximum 1 foot deep		Minimum 1 foot deep	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	° F.	° F.	° F.	° F.	° F.	° F.
Open	99.4	±19.2	74.6	±11.7	70.0	±10.0
Brush	86.7	±17.6	71.1	± 9.8	68.2	± 9.9
Difference	12.7	± 1.4	3.5	± 1.4	1.8	± 1.3
Denuded	103.2	±18.1	77.2	±11.5	-----	-----
Undenuded	97.0	±18.0	75.9	±11.8	-----	-----
Difference	6.2	± 1.3	1.3	± 1.1	-----	-----

¹Maximum temperature oil-well thermometers were used to measure surface temperatures. The mercurial bulb was ½ inch long and ⅜ inch in diameter. The thermometer was placed approximately parallel to the surface, with half the bulb submerged in the soil and the upper half covered with a thin film of surface soil. Temperatures at 1-foot depth were obtained with thermometers of incubator style.

Table 25.—Frequency of occurrence of low soil-moisture content as influenced by forest conditions and treatment, Choctawhatchee National Forest, 1930-31¹

Forest condition and treatment	Soil moisture less than 3.0 percent at depths of—			Soil moisture less than 1.5 percent at depths of—		
	1 inch	4 inches	18 inches	1 inch	4 inches	18 inches
	Number of days					
Grassy opening:						
Trenched	26	18	15	17	8	0
Untrenched	28	20	18	18	5	4
Denuded opening:						
Trenched	28	7	2	7	0	0
Untrenched	34	16	18	19	5	2
Scrub oaks, untrenched	26	22	23	14	5	6

¹Wilting coefficient for longleaf pine on deep Norfolk sands is reported to be 1.75 percent, hence a moisture content of less than 1.5 percent is critically low. Weekly determinations during 1931 showed that moisture content at all 3 levels simultaneously fell below 1.5 percent 3 times in natural openings, and only once under scrub oaks.

similar effects being manifest to a depth of about 1 foot (Table 24). Shrubby and herbaceous ground cover together shortened the most dangerous period for seedlings by adding about 2 months to the favorable period following germination. Soil moisture fell to a critical level several times, under all conditions tested except in pine

stands (Table 25). The general effect of cover, however, was to lower temperatures, reduce evaporation, and conserve moisture in the upper soil layer.

It was also found that moderate shade and some oak litter and pine straw favored seedling establishment on deep sands by retarding loss of soil moisture and checking overheating and desiccation of soil. These influences, however, favored survival and growth in the early stages only. Later, when seedlings need more moisture and can either tap deeper soil layers directly or draw capillary moisture from them, survival was best in open, unshaded places. Where seeds were available, pine seedlings on the Choctawhatchee were most abundant under a light pine overstory (or with no overstory) and in the presence of oak shade (Table 26).

Table 26.—Combined effects of density of pine stand, frequency of fire, and number of oaks on numbers of longleaf seedlings, Choctawhatchee National Forest, 1930¹

Density of pine stand	Frequency of fire	Pines per acre		Oaks per acre		Trees and sprouts
		Seed trees	Seedlings	Over 4½ feet ²	Under 4½ feet	
		Number	Number	Number	Number	Number
Medium	Rare	29	133	253	974	1,227
Light	Do.	4	154	526	748	1,274
Do.	Periodic	1	256	184	4,592	4,776
Open	Do.	0	0	1,140	3,890	5,030

¹Based on complete counts on 25 1/40-acre plots at 2-chain intervals along random lines run by F. W. Bennett. As each oak sprout was counted individually, regardless of its proximity to other sprouts, these figures cannot indicate the smaller numbers of oaks which will eventually dominate on such areas.

²More than half of all oaks above breast height fell into 2- and 3-inch diameter classes. These trees were about 25 years old and 12 to 15 feet high. The largest seldom exceeded 18 inches in diameter, 40 feet in height, and 75 years of age.

Clear cutting of the heavier longleaf pine stands provided unencumbered growing space for the few established seedlings. In a forest receiving only nonintensive care it is unfortunate that conditions favoring early survival differ from those favoring later establishment and growth. In most pine stands on the Choctawhatchee—especially those not burned severely—longleaf seedlings were found in grass litter and under scrub oaks, particularly in and around the pines. Where seed trees were scarce, the few seedlings present were in the shade of scrub oak or pine seed trees. Ultimate survival was therefore possible only for the few that were advantageously located; the rest died as a result of competition from their former nurse trees. It is not likely that many seedlings died from exposure following premature removal of overwood. However, success did not always follow release at the correct stage; many seedlings succumbed to hogs, disease, or fire. Table 26 shows the combined effects of fire, density, and stand associates on the establishment of longleaf.⁸

The denser virgin stands contained no reproduction because they utilized the site so completely, while reproduction in some lighter stands was lost because of surface fires. Fires in the well-aerated and waxy mat of pine straw were relatively slow in contrast to flashy grass fires, but more uniform in intensity and complete in

⁸Lightning fires were common and some of them formerly burned large areas—but probably less than 0.5 percent of the forest annually—thus affecting a given tract few times during the life of a pine. Settlement probably increased the frequency of burning but reduced the accumulation of combustible materials, thus leaving little to burn.

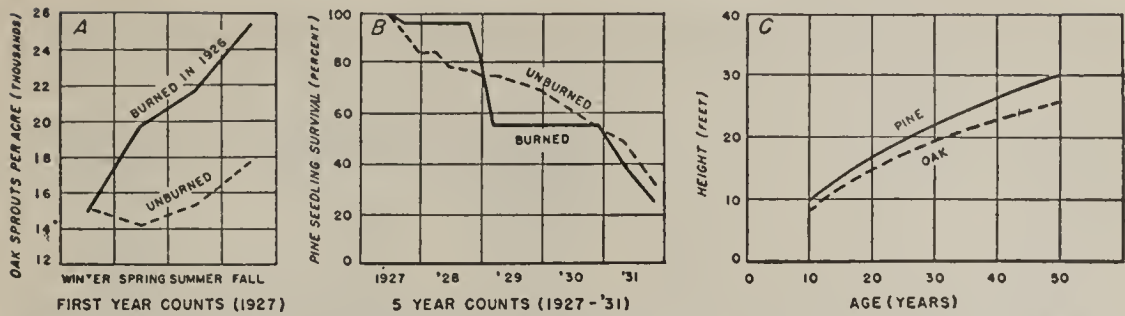


Figure 32.—Competitive relationships between oak and longleaf pine on burned and unburned areas: *A* shows that thousands of scrub oak sprouts per acre are added to a stand after fire; *B*, longleaf survives nearly as well on burned as on unburned areas; *C*, above breast height longleaf has a somewhat more rapid height growth than associated oaks. Choctawhatchee National Forest.

coverage. The fires in oak litter were intermittently rapid, irregularly intense, and spotty, hence more seedlings there escaped death.

It should be kept in mind that while the resistance of longleaf seedlings increased with size and vigor, their unusually slow growth on these poor sites postponed immunity. No yearling and few second-year seedlings are fire-hardy. Thereafter, fires kill the weaker seedlings as well as stronger ones in hot spots. In general, mortality varies with age of seedlings, vigor when the first fire comes, and frequency and intensity of subsequent scorching. As noted before, at 15 to 20 years of age, when longleaf seedlings are 2 to 4 feet high, they usually survive burning. Moreover, as the crowns of the larger trees close, underbrush thins out and fire hazard diminishes.

Clumps of scrub oaks create a high fire hazard because their dried leaves, especially those on lower branches less exposed to wind, persist on the twigs until mid-winter. This dead foliage may be a cause of crown fires in spots. The usual surface fires do not kill back the larger oaks but the tops of smaller ones are often killed to the ground.

As only a small number of oaks were over 3 inches in diameter in the Choctawhatchee study, it was thought that fire could be used to inhibit height growth of oaks, weaken the sprouts, and release space—above if not below ground—for pine seedlings. Accordingly, the effects of accidental fires on scrub oaks were studied (Table 27 and Fig. 32). As expected, fire periodically set back the height of sprouting oaks but apparently failed to weaken them. Burning stimulated coppice growth and increased the numbers of stems of all oaks except turkey oak, which maintained its place because of superior aggressiveness and fire resistance.

Once firmly rooted, both pine and oak were fire resistant (Fig. 32, *A* and *B*), and competition began (Fig. 32, *C*). The eventual dominance of most longleaf seedlings, regardless of fire, may be ascribed to early tolerance of light shade, deep root penetration, and later sustained height growth (Pls. 18 and 19).

It was found that fire hazards accumulated very slowly, the thin stands of grass leaving mineral soil exposed for seedbeds; brown spot was not severe, the less fire-hardy pines did not encroach, and moderately intense fires failed to reduce oak brush. For these reasons, the continued exclusion of fire is deemed feasible.

Table 27.—Effect of 3 uncontrolled winter fires during 5 years on a sprout stand of 4 species of scrub oak associated with longleaf pine on deep Norfolk sands, Florida¹

Fire treatment and species	Original stand (sprouts)	Stand after 5 years compared to original stand	Change in volume of foliage
	<i>Thousands</i>		
Unburned:	<i>per acre</i>	<i>Percent</i>	<i>Percent</i>
Turkey oak	7.20	81	— 5.8
Bluejack oak	1.75	153	+ 38.5
Live oak	3.37	179	+ 82.2
Post oak	2.87	167	+ 72.9
Total or average	15.19	127	+ 25.4
Burned, 1926, 1928, 1930:			
Turkey oak	10.92	101	+ 9.3
Bluejack oak	1.73	139	+ 32.5
Live oak	1.83	288	+ 164.2
Post oak57	2,216	+ 1,683.7
Total or average	15.05	208	+ 85.2

¹Basis: Six 1/100-acre sample plots in each fire treatment, Choctawhatchee National Forest.

COMPETING VEGETATION AND DISEASE

The chief problems in establishing longleaf reproduction involve the handling of competing vegetation and disease. While longleaf endures adversity better than any other species of southern pine, it is intolerant of shade, which retards synthesis and the storage of plant food necessary for active height growth.

Light is but one of many factors which interact to produce variations in seedling habitats. Root competition restricts the growth of trees, both large and small. For seeds to penetrate the rough, reach the soil, germinate, take root, and survive one year is not enough to guarantee successful reproduction. Subsequently, the dwarfing effect of fire, brown-spot disease, or other injuries, along with other adverse factors, such as dense young growth, poor sites, shady locations, grass competition, or overwood, may suppress and eliminate entire seedling stands.

Density

The importance of density in the growth of forest stands is universally recognized. In this connection, total coverage or full stocking of openings, rather than excessive numbers of seedlings, is the primary objective, because thin spots or blank spaces in new stands of longleaf often fill in too slowly (if at all) or with inferior species. Thick spots usually take care of themselves through natural thinning. This occurs promptly in most intolerant species but is tardy in longleaf, owing to the ability of dwarfed seedlings to cling to life—often 15 to 20 years or more—without appreciable growth.

In pure longleaf stands, the expression of dominance is inconspicuous in the early grass stage, but very pronounced during active height growth.⁹ Fire or other

⁹An early expression of dominance means early victory for the majority of those trees which will make up the final stand. Deen (144) lists 7 factors which promote or retard early expression of dominance in white pine: inherent characteristics, size and origin of seed, site, variation in age, density, disease or insects, and treatment. In a crowded stand, where competition is keen, various causes may contribute to the elimination of certain individuals. As pointed out by Hauch (266), some seedlings are weak from

Table 28.—*Effect of density on the height of pure stands of 11-year-old longleaf pine suffering from brown-spot disease (After Wakeley)*

Seedlings per acre (number)	Burning treatment since 1920 ¹	Portion of stand 1 foot or higher	Average height		
			All seedlings	Tallest 1,000 per acre	Tallest 200 per acre
		<i>Percent</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
47,110	Unburned	7.2	0.35	3.32	8.45
15,000	Nine annual fires	14.0	0.55	3.88	7.25
2,247	Unburned	34.7	2.33	4.94	17.03

¹This area near Bogalusa, La., was exposed to annual burning prior to 1920, and was burned in September 1920 to prepare for the heavy seed fall of that year, from which the seedling stands originated following clear cutting of the virgin trees.

density-reducing agencies temporarily restrict the range in size between large and small seedlings by killing the smallest ones. Reduced density hastens the later expression of dominance (Table 28).

With a thin herbaceous ground cover, brown spot may contribute to early expression of dominance by destroying the weaker seedlings. Under average ground cover and with low brown-spot infection, early height growth is relatively uniform. On a thick grass rough, however, the disease may retard the expression of dominance.

Serious overcrowding in the grass stage delays emergence and often adds several years to rotation periods. Congested stands (165,000 seedlings or more per acre) become heavily diseased. This is followed, at 10 to 15 years of age, by general stagnation. In thinner but still overstocked stands (40,000 to 140,000 seedlings per acre) the height of dominant seedlings varies inversely with density. At 20,000 seedlings or less per acre, the height-density relationship is curvilinear. High density retards height growth, whether the stands are burned over or not. Most significant, from the practical standpoint, are the average heights in the portion of the stand emerging from the grass, e.g., those 1 foot or more in height.

Stands of 2,000 or 3,000 seedlings per acre shoot up more promptly than those stocked with 10,000 or more. In densities of 100,000 to 200,000 per acre at 11 years of age on good sites, hardly any specimens may emerge from the grass at 7 years; at 10 years, only 200 to 1,000 may be 6 to 30 inches high, and but a few higher. Fortunately, extreme density is rare in longleaf seedling stands.

Effects of Vegetative Competition

Vegetative competition is one of the most serious problems faced by longleaf seedlings. Bryant (58) found that in the virgin forest accumulations of brush dense enough to interfere with seedling development did not as a rule cover more than 5 percent of the area. Advance reproduction, if any, was not destroyed by animal logging removing 6,000 to 8,000 board feet per acre, because some seedlings withstood severe bruising in skidding operations. Moreover, skidding disrupted no more than about a quarter of the forest floor. At least 70 percent of the ground studied by Bryant was undisturbed, open, and, except for extensive thin grass, available for

the start, some are handicapped early by small size, and still others are retarded by later injuries. Prolongation of this competitive process, particularly in even-aged stands, is an undesirable addition to the length of rotation for forest crops. As density decreases there is an increase in average diameter and in its standard deviation. This means greater variation and increased expression of dominance.

new seedlings. After logging, however, thickening masses of grass and weeds, along with shrubs, diminished the seedlings' opportunities for survival. Some of the effects of grass are favorable to seedlings and others adverse. Grass robs them of soil moisture during life, but its roots contribute soil organic matter after death. Furthermore, dead grass tops shield tender seedlings from frost and other injurious agents. On the other hand, dead grass seems often to smother small seedlings.¹⁰

Various attempts have been made, in both laboratory and field, to discover the effects of grass on longleaf seedlings. In one study,¹¹ seedlings were grown for 2 years in greenhouse containers, with and without native grasses (*Andropogon scoparius* and others), and the grass cultures were clipped back twice a year and the clippings discarded. Others were burned over annually, an artificial barrier protecting the pine foliage from heat, and the ashes left in place. In such experiments no significant variations were detected in root and needle length of longleaf seedlings, but dry weights were heaviest without grass competition. With grass, the best development was in burned-over cultures, next best in clipped ones, and poorest in undisturbed cultures or rough. This relationship held for each of two degrees of watering, regardless of grass species.

Table 29.—Height of 4-year-old longleaf seedlings under 4 ground-cover treatments (452)

Additional treatment	Spaded	Denuded	Burned	Rough
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
None	5.8	29.0	2.7	2.5
Watered	4.3	29.4	2.3	5.8
Fertilized	5.7	30.2	3.0	4.1
Watered and fertilized	5.4	29.2	3.0	2.0
Mulched	4.3	14.5	3.1	6.4
Mulched and watered	5.4	25.8	5.6	9.9
Mulched and fertilized	8.7	32.6	3.6	6.5
Mulched, watered, and fertilized	6.6	25.9	2.9	6.0

Field tests have likewise demonstrated the superiority of seedlings kept healthy by spraying to eliminate brown spot and grown without the grass that normally surrounds them (452). Three-year-old seedlings raised on spaded plots were twice as tall as those on annually burned or rough plots; on plots kept denuded, they were about 10 times as tall. This experiment also indicated that various combinations of fertilizer, water, and mulch exerted no significant influence on the seedlings. By the end of the fourth growing season more than two-thirds of the seedlings in the denuded plots were growing rapidly, but on other plots nearly 95 percent were still in the grass. The average height of seedlings in the denuded plots given no additional treatment was over 11 times that of seedlings in the rough plots (Table 29). Also, the average height of seedlings in denuded plots was much greater than that in the spaded, burned, or rough plots given supplementary treatments.

The outstanding growth of sprayed seedlings on denuded ground suggests possible release treatments for stunted seedlings. Denudation without the use of a

¹⁰This stifling action of accumulated grass or heavy litter kills many longleaf seedlings, especially on areas not burned over for 3 years or longer, because their short stature permits them to be covered up so easily. Also, under such a cover, seedlings intolerant of shade suffer from starvation.

¹¹Pessin, L. J., and Chapman, R. A. The behavior of longleaf pine seedlings when competing for moisture and nutrients. 1939. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

fungicide merely intensifies the disease. Timeliness of a remedy depends on recuperative capacity, and this in turn varies with certain internal and external influences (genetic, physiological, or environmental). Specifically, nutrition, food storage, and sprouting ability should be taken into account in judging the possibilities of restoring vigorous life to a longleaf stand stunted in its grass stage.

Many plants, of course, store organic food in their stems, but longleaf pines may suffer from undernourishment while their stems slowly thicken. In nursery studies of nearly stemless yearlings, Huberman (310) found that an 81-percent increase in the dry weight of seedling tops between December 2 and January 6 was accompanied by no appreciable elongation of needles or opening buds. The obvious explanation, although not checked by chemical analyses, is that storage of food in the needles took place during the winter. This assumption is borne out by (1) the prevalence of winter temperatures high enough for photosynthesis; (2) marked reduction in the survival of planting stock experimentally shaded or defoliated during December and January; (3) relatively great length of the spring internodes of longleaf pine compared with those formed later in the season, and (4) the springtime occurrence of a peculiar nonspotting phase of brown spot in which whole needles were invaded rapidly by the pathogen, and the host tissues turned yellow in a manner indicating sudden transformation of insoluble to soluble food reserves in the needles.

If not retarded by disease or other stunting agents, the assimilation of currently formed and stored food produces a well-rooted and sturdy-stemmed seedling. Thereafter, considerable amounts of organic food in the form of starch are stored in the thick, soft cortex, in the central pith, and in the wood rays of the taproot.¹²

In the grass stage, longleaf may sprout after mechanical or fire injury through the development of adventitious buds (Pl. 20).¹³ Stored food used by the sprouts must be replaced; if seedlings are repeatedly deprived of second-year foliage, they gradually starve.

Greenhouse experiments have indicated that native grasses (*Andropogon* spp.) impede the growth of longleaf seedlings (453). Field tests revealed the extent of this retardation. In southeastern Louisiana, on predominantly Ruston fine sandy loam, dense stands of stunted 12-year-old longleaf in the grass stage were released by weeding and thinning (446). Seven plots were denuded and the seedlings were thinned to densities of 1,000, 5,000, 10,000, 15,000, 25,000, 50,000, and 100,000 per acre. In 7 other plots on the same area, thinned to the same densities, only oaks were removed, leaving the herbaceous cover. On another plot, pines were thinned to 5,000 per acre without disturbing the herbaceous cover or removing the oaks. All seedlings were sprayed to control brown spot.

The original height of the seedlings on all plots in 1932 was 0.1 to 0.3 foot; the diameter at the root collar varied from 0.3 to 0.9 inch, averaging about 0.6 inch. Over a subsequent 5-year period seedlings on each denuded plot grew 2 or 3 times as

¹²The pith, however, is not as large in roots as in stems. Because the cortex is relatively wide, it is the primary storehouse for food. In 12-year-old seedlings in the grass stage, it was found that the cortex formed 87 percent of the basal area below the root collar. Pessin, L. J. The sprouting ability of longleaf pine. 1932. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

¹³The natural replacement of tops of stunted 12-year-old pines has been observed following springtime severance of the original tops with a hoe $\frac{1}{4}$ to $\frac{1}{2}$ inch below the ground surface. Except in areas where grass also was removed, new tops were regenerated by November, but many of them were double.

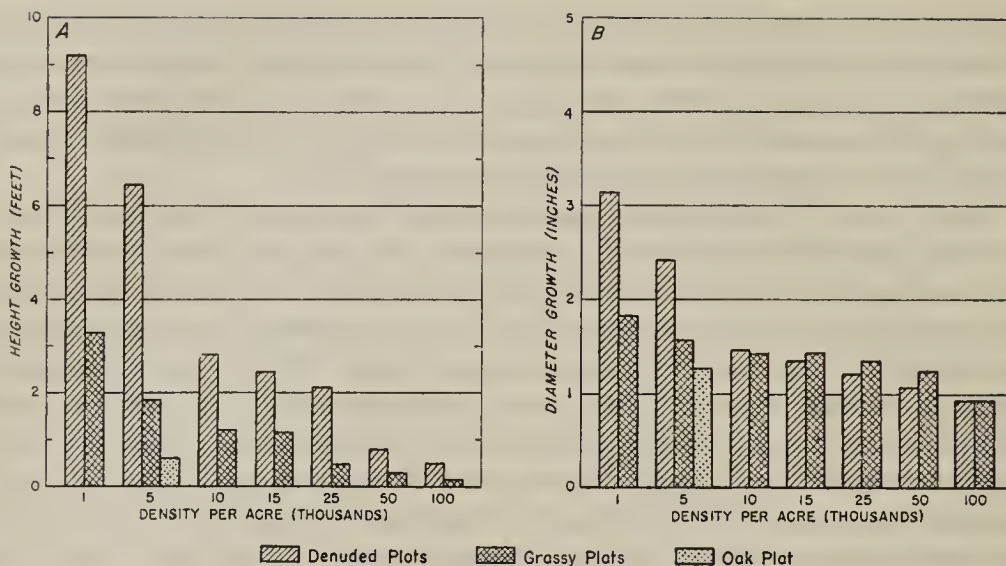


Figure 33.—Effect of thinning and denuding on dense stands of longleaf seedlings. *A* and *B* show the effect 5 years after release treatments on 12-year-old seedlings, all less than 4 inches high and 0.9 inch in diameter at the ground. Note that thinning, spraying, and denudation immensely stimulated height growth, particularly at the lower densities. The response in diameter growth was less marked.

rapidly in height as those on a nearby grassy plot of equal density (Fig. 33). Seedlings showed the best growth in the sparsest stands in each treatment class. Scrub oaks inhibited the pine seedlings. Dwarf specimens made spectacular growth when the stunting agents—in this instance other seedlings, associated grasses and brown spot—were eliminated (Pls. 21 and 22).

In the forest, crowding of longleaf seedlings is rarely encountered; there is usually a dearth rather than a surplus, but encroachment by grass is common. In badly diseased stands, herbaceous plants and grass may shield the seedlings from fatal increases in brown spot, but as a whole they hinder growth. Hence the release of backward specimens from all vegetative competition, as indicated by the above studies, is highly desirable where needle disease may be controlled. If labor is cheap and spray can be used, surface vegetation should be removed within a radius of 2 to 3 feet around seedlings needed for crop trees. If the cost is prohibitive, prescribed burning is recommended as a thinning, weeding, and sterilizing agent (105).

Root Competition

Many arborescent species are better able to tolerate shade in juvenile than in adult life. Longleaf pine is an exception, perhaps only because of its protracted stay in the grass. The intolerance of longleaf (Table 30) often has been observed but usually interpreted purely as a demand for light (497, 489, 315). Except on the most acid soils, seeds newly germinated in the shade are more likely to die from damping off (407) or root competition than from insufficient light. In Figure 25, for example, the effect of overwood shade is less prominent than surface treatments in effect on survival because the seedlings remained in the grass for a long time. Later, the roots face overwhelming competition from established roots of overtopping vegetation. The sturdiest longleaf seedlings invariably develop in full sunlight, but

Table 30.—*Effect of overwood on natural establishment of longleaf seedlings on cut-over lands grazed and periodically burned, southern Mississippi, 1925*

Item	Seedling position		
	Directly under trees ¹	Among and between groups ²	Open, away from all trees ³
Area	Acres 10.8	Acres 14.0	Acres 3.0
-----Number per acre-----			
Unestablished seedlings:			
Stemless grass stage	279	257	4,613
Stem under 6 inches	55	137	228
Total	334	394	4,841
Established seedlings, by height classes:			
1 foot	9	29	153
2 feet	6	26	20
3 feet	0	1	13
	15	56	186
Total, all seedlings	349	450	5,027

¹Maximum overhead shade.²Partial overhead shade.³No overhead shade.

only if moisture is sufficient. Root competition, rather than shade, accounts for the absence of seedlings under the open crowns of trees, and for their appearance—or at least persistence—in openings at some distance from such trees (91). In brief, the location of competing roots primarily determines which seedlings will be suppressed and ultimately killed.

Longleaf is a species with many formidable deep-rooted competitors. On pine sites the restraining effect of competing hardwoods largely passes when longleaf overtops them. However, a leading pine shoot may be outstripped by its neighbors unless its roots extend below those of its competitors. For this reason it is believed that dwarf post oak, for example, offers much more serious competition than other scrub oaks (17). The small superficial root system of blackjack oak appears to present relatively little competition. At all events, by midspring, after establishment during the preceding fall, longleaf roots may have descended beneath those of oaks and reached a lower supply of soil moisture. Since longleaf grows better among blackjack than turkey oaks (604), it is fortunate that on the sandhills of North Carolina and Georgia the species is usually associated with blackjack, which tends to replace the turkey oak with which the pines started (603, 17). Except in dense stands, blackjack and bluejack oaks may have useful functions as nurse trees

USE OF FIRE TO FACILITATE REPRODUCTION

Until about 10 years ago, wild grass and forest fires were generally regarded as an unmitigated evil in the South. Since then, the attitude of informed foresters towards woods burning in the longleaf belt has changed radically.

Even before experimental evidence was available, a few keen observers recognized some of the beneficial effects of fire. Thus, a report from South Carolina in 1907 affirmed that judicious burning on a winter night is harmless to young longleaf seedlings (475). In 1909, Bryant declared that "heavy growth of grass and ferns

springs up after logging and in 2 or 3 years this becomes so dense that the herbage must be burned off previous to the fall of seeds, so that they can reach the mineral soil" (58). He concluded that when reproduction is delayed for several years through the failure of a seed crop to take effect, as often happens, grass secures a strong hold. Formation of heavy sod then offers a serious obstacle to reforestation because seedlings are smothered out before they can attain sufficient root development. Burning off the ground cover is consequently essential, and during seed years this should occur late in the calendar year, prior to seed fall and before logging. Refuse after logging should consist only of unmerchantable logs and tops. If felling occurs between seed crops and the land remains unseeded for more than a year subsequent to logging, it is necessary to burn off the ground cover again before seed fall.

In 1914 Buttrick reported that 1-year-old longleaf seedlings often withstood surface fires in a single year's accumulation of litter. With favorable soil, moisture, and light conditions, seedlings withstood annual fires after their first season, but with retarded height growth (71).

An unmistakable example of the successful reproduction of longleaf as a result of surface fire, in contrast to its failure on an adjacent unburned area in Floyd County, Ga., was reported by Andrews in 1917. On the deep sands of western Florida, the greatest success in reproduction was attained on areas logged during or immediately after seed fall.¹⁴ In Louisiana, the ability of longleaf to succeed itself was doubted by many lumbermen (290) until it was demonstrated at Urania about 1928 by Hardtner¹⁵ and Chapman on land burned annually before seed fall. Thereafter success on this area was attained regardless of burning treatments, but only where hogs were fenced out. Continuous annual burning also partly controlled brown spot, but reduced sapling height growth during the first few years.

About the same time, it was shown that careful management of cut-over forest areas in Mississippi, including annual burning until trees rejected in an earlier cutting produced a good crop of cones, brought highly beneficial results (606). The area was burned over before the seeds matured so that they fell on exposed ground rather than on dead grass. Sheep and cattle were allowed to graze freely, but hogs were kept out. For 2 years following the appearance of longleaf seedlings, fires were excluded. Afterwards the land was burned annually when there was little wind and the ground was sufficiently damp to prevent damage to the seedlings.

In field tests with hand-sown seed, the advantage of free access to mineral soil exposed by fire has been repeatedly manifest. In one instance, 6 sowings protected from predators showed 50-percent germination and 84-percent survival on burned-over ground, compared with 35-percent germination and 75-percent survival on an unburned area (470). In other tests in Louisiana, germination and survival were greatest on bare plowed soil and next best on closely grazed carpetgrass on fire lanes. Continued grazing on carpetgrass, however, precludes survival, because limited areas of carpetgrass are almost invariably grazed too closely by cattle to carry surface fires.¹⁶ Partly exposed soil, not completely covered by native grasses, produced high

¹⁴E. W. Gemmer, in a letter to Forest Supervisor A. C. Shaw, Nov. 28, 1928.

¹⁵Hardtner astonished many of his fellow conservationists by wholeheartedly endorsing early reports advocating the use of fire for constructive purposes in the woods (236, 100).

¹⁶Longleaf pine seeds germinating on such areas survive less than a year because of severe trampling (584).

survival in these tests. A thin litter of hardwood leaves was very favorable to germination; but pine straw was unfavorable and a 2 or 3 years' accumulation probably excluded seedlings entirely. Native grasses unburned long enough to form a tangled mat were most obstructive (Pl. 23). On many ungrazed areas, 3 years without fire produced this condition.

In a test on the Olustee Experimental Forest in northeastern Florida it was found that the longleaf pine catch was greatly enhanced on seedbeds prepared by burning immediately preceding seed fall, if birds and rodents did not interfere. Where such depredations were imminent, a prescribed burn about 10 months before seed fall was indicated. These and many other experiments show that longleaf is frequently benefited by fire.

What are the effects of fire on longleaf? The delicate, unligified, and barkless seedlings usually fail to withstand contact with flame in the first few weeks or months of their existence. In the cotyledon stage, seedlings occasionally survive on areas burned over annually because they are so tiny and close to the bare ground that fire in the surrounding grass passes harmlessly around them. Thus, fair survival may be expected where grass is thin, but as a rule fire in dense grasses is fatal to longleaf in the cotyledon stage.

In the fire-resistant grass stage, losses from fire are normally low, defoliation not proving fatal unless too recurrent. In diseased stands the loss of growth from defoliation may be more than offset by gain from sanitation. The life history of longleaf seedlings emerging from the grass stage on the "Roberts plots" in Louisiana illustrated this point. These included two adjacent $\frac{1}{4}$ -acre plots, both seeded naturally in 1913 and fenced against hogs; one was protected and the other burned over annually. Inventories on the annually burned plot mounted in spite of five successive fires. During the subsequent 20 years fire losses were no greater on the burned plot than losses from all causes (excluding hog damage) on the adjoining unburned control plot (Fig. 43).¹⁷

In the fire-resistant, active-growth stage, defoliation from fire can be appreciable and yet kill few seedlings. Among seedlings 6 inches to 2 feet tall, the most susceptible to fire damage are those half defoliated by disease but with many dead needles adhering. In general, the losses on burned-over areas follow the mortality trends typical of development in comparable unburned stands.¹⁸

Intense fires kill many seedlings of a certain height—between 6 and 18 inches in some places (290), and 1 and 3 feet in others—regardless of the season. The location of terminal buds in the zone of maximum heat may explain the fact that high mortality is sometimes confined to a certain height range. This, however, is by no means universal. At a height of 2 or 3 feet the long needles tend to protect the terminal bud, and fire usually kills only seedlings previously weakened by brown spot or other causes (Pl. 24). In one test, tissue paper placed around the buds of seedlings 1 to 3 feet high was not even scorched though the needles were scarred to within 3

¹⁷In the absence of new seedlings from subsequent seed crops a mounting inventory is attributed to failure of observers to find all seedlings in the early counts.

¹⁸For example, in a 7-year rough, an incendiary fire burned 800 acres of natural reproduction after needle growth had started in the spring, killing only 10 percent of the 7-year-old seedlings. Foliage of the previous year on the survivors was mostly consumed by the flames, but the new needles, with tips burned off, continued to elongate. Scorched ends were visible in June on otherwise uninjured needles.

Table 31.—*Effect of burning before seed fall on establishment, survival, and early growth of longleaf seedlings from the 1935 seed crop on the Kisatchie National Forest, La.*¹

Item	Examined Jan.-Mar. Year	Age of rough at seed fall (years)			
		0	1	2	3+
Cones per acre.....		Average number 1,036	Average number 1,002	Average number 551	Average number 1,223
Seedlings per milacre.....	1936	31.1	37.3	14.1	35.7
	1937	6.2	7.2	2.0	3.0
	1938	4.6	7.4	1.3	2.4
	1939	4.9	7.3	2.4	2.7
Seedlings per cone.....	1936	30.0	37.3	27.7	29.2
	1937	5.9	7.2	3.8	2.5
	1938	4.4	7.3	2.3	1.9
	1939	4.8	7.3	4.4	2.2
Proportion of area stocked with 1 or more seedlings per milacre.....		Percent	Percent	Percent	Percent
	1937	75	86	55	62
	1941	70	78	46	48
Average diameter of seedlings at ground line..		1/32 inch	1/32 inch	1/32 inch	1/32 inch
	1938	10.5	10.7	9.8	9.8
	1939	17.3	17.5	16.7	16.7
Average height of seedlings		1/100 foot	1/100 foot	1/100 foot	1/100 foot
	1939	9.1	11.2	8.0	11.9

¹The scattered milacre samples on which these figures are based aggregated over 2 acres. The task of making repeated inventories precluded the tracing of individual seedling's case histories. After the inventory of January 1937, each treatment shows an apparent gain in number of seedlings. Since essentially no seed has been produced on the area since 1935, these variations are due to inescapable errors in counting. The increase in accuracy resulting from the extensive sample more than offsets the disadvantage of not having individual case histories.

The most conspicuous mortality occurred in the excessively warm first summer (1936) while the seedlings were in their cotyledon and primary-needle stage. The "tree percent" of the best area on the basis of seed yields per cone was not over 15 at the end of the first year. Bickford, C. A. Some observations on the use of fire in regenerating longleaf pine. 1939. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

inches of the bud (105). Under controlled or moderate burning, the percent of survival tends to rise uninterruptedly with height of seedlings. Summer burning usually increases damage.¹⁹

In the absence of fire, longleaf seedling stands are often reduced severely by disease and competition from other vegetation. Areas deteriorated in this manner can be partially restored by later improvement cuttings, but are likely to yield only a scattered stand of timber—delayed at least 10 years in reaching maturity (111).

Fire as a Tool in Seedbed Preparation

The results of a "pilot plant" investigation that succeeded in obtaining longleaf reproduction with the aid of fire are shown in Table 31. Survival was greatest on areas burned in winter 1 year before seed fall, next highest on areas burned immediately before seed fall, and definitely lower on areas burned 2 or more years before seed fall. It was found that under proper conditions burning could be done at night in 20- to 300-acre blocks at a cost of 0.01 to 0.10 man-hour per acre, excluding cost of established firelines.

¹⁹This was demonstrated in an uncontrolled fire on a 9-year rough at Urania, La. Summer fire killed 87 percent and winter fire 51 percent of the seedlings ½ to 4 feet tall. Summer fire killed 38 percent and winter fire 10 percent of the saplings 4 to 15 feet tall. In prescribed burning, combustion is less intense and losses are lower regardless of the time of year, though burning in the growing season is not desirable. A controlled winter fire killed less than 1 percent of the seedlings from 1 to 3 feet high, but an incendiary fire on a hot windy afternoon in March killed from 35 to 50 percent of the seedlings in this class (Pl. 24). Less than 5 percent of the seedlings in the grass were killed.

In using fire to prepare a longleaf site for reseeding, it is of the utmost importance that burning be done at the right time, preferably in the winter before an expected heavy seed fall, although an autumn burn immediately before seed fall may succeed. Fortunately, a heavy seed crop, as already observed, is heralded by an abundance of immature cones two summers before. Unpredictable hazards such as onslaught of cone insects or disease may invalidate such predictions, but site preparation should not be neglected because of this possibility.

To subdue brown spot, fire should be used only as and where needed. The sanitary effect of a fire increases with the area covered. The vitality of seedlings and their capacity to recuperate from defoliation must be considered. Burning should be done before the seedlings have been seriously weakened by disease; otherwise many will be killed by fire. Fire should be used as soon as brown spot threatens to hinder the development of dominant seedlings. Thus, a burn is indicated when the average loss of needles is at least 35 percent in late fall or early winter, because if omitted the foliage on most seedlings will be shed by the following March or April, and the spreading disease may so weaken the seedlings as to render them incapable of withstanding subsequent fire treatment.

Summing up, it may be concluded that the relationship of fire to longleaf regeneration is as follows:

1. Fire along with the absence of cutting accounts for the extensive pure stands of virgin longleaf.

2. Ordinary winter surface fires may cause heavy mortality to seedlings in the first year after germination, and appreciable though far less serious loss in the later grass stage. Resistance of larger trees to fire is normally very high.

3. Seedlings under complete protection from fire are most seriously stunted by brown spot and grass competition.²⁰

4. Annual surface fires are most effective in reducing brown spot and grass smothering but they give the scorched and partly defoliated seedlings less opportunity to recover than do fires at longer intervals. Thus annual burning may hold back the seedlings in the grass stage, much as brown spot and grass do under protection.

5. Burning at intervals of 2 to 10 years, depending on the amount of competing vegetation and prevalence of disease, permits longleaf seedlings to emerge from the grass. Periodic fires destroy or set back competing hardwoods and other pines sufficiently to enable longleaf to dominate in places where complete protection would bring opposite results.

6. A surface fire late in the winter, or 8 to 9 months before a heavy seed fall, gives longleaf an initial advantage in reproduction by exposing enough mineral soil to make a good seedbed, yet permitting the growth of a thin stand of grass and weeds sufficient partially to hide the seed from birds.²¹

²⁰This statement may seem paradoxical in view of the recognized increase in thrift of grass under frequent burning. The increased bulk of living roots and tops leads to greater transpiration. On the other hand, the weaker growth of grass on protected areas accumulates a mass of dead herbaceous material that injures through smothering both pine seedlings and grass. This is most serious for backward seedlings that fail to emerge promptly.

²¹Professor H. H. Chapman suggests the following program for regenerating longleaf on land bare of seedlings: (1) burn before seed fall; (2) permit very light grazing in the first two years after seed fall; (3) burn at the end of the second or third year; (4) burn at the end of the fifth year or just before height growth begins.

SUMMARY

No phase of forestry presents more complex and critical problems than does forest reproduction. Solutions depend on understanding the prerequisites of the process, the characteristics of seed-bearing trees and forest seed crops, and the possible causes of failure after seed fall.

On most longleaf pine sites the grass and litter must be burned off for seedlings to catch in appreciable numbers. On deep, sterile sands the vegetative cover is so sparse that no site preparation is needed for seeds to contact a mineral seedbed. Here the loss of seed and seedlings is so high that the regeneration period must be at least 15 years. Mortality is excessive because of the abnormal length of the grass stage of seedlings on these sites. On sites where seedlings remain fairly healthy, most of them emerge from the grass in 6 or 7 years.

Capacity to survive the grass stage depends upon the complex environment presented by competing vegetation and injurious agents. Longleaf seedlings compete for growing space with other seedlings, grasses, weeds, shrubs, and larger trees. Competition with each other in this stage is not serious where density is less than 5,000 to the acre. In the absence of injurious agents, seedlings normally dominate the minor competitors but not the shrubs and trees. Some trees possibly benefit small seedlings for a brief interval if moisture is scarce in surface layers of soil, but they presently become very damaging.

When weakened by biotic agents or mechanical injuries, longleaf seedlings readily succumb to competition of minor vegetation. In the absence of fire, the weaker seedlings usually die gradually from smothering by dead grass or litter, from brown spot, or from a combination of the two. Rarely are many seedlings killed by insects or animals, except range hogs. After the first or second year, direct mortality from fire is not common, although throughout the grass stage burning more often than every 2 years has a debilitating effect.

In general, longleaf pine seedlings usually come in best on a forest floor with a 1-year rough, normally emerge from the grass in about 6 or 7 years if fairly thrifty, and reach breast height at 9 or 10 years of age. This development occurs, however, only if seedlings are not seriously damaged by fire, hogs, disease, smothering, or overtopping.

Dense seedling stands tend to be heavily diseased and in the absence of burning linger in the grass. Thick stands of grass and weeds, a heavy cover of litter, or too frequent or severe fires may likewise delay seedling growth. Anything that repeatedly deprives seedlings of second-year foliage brings gradual starvation. The shade and root competition of overwood suppresses many seedlings that succeed in emerging from the grass.

As a rule, burning at intervals of 2 to 10 years can do much to facilitate longleaf regeneration. The timing of the fires depends on the need for site preparation, sanitation, weeding, hazard reduction, or other desirable benefits.

VII. Artificial Regeneration

PLANTING has much to recommend it in preference to natural processes of reproduction. Unless everything is favorable, Nature's method of reforesting the land is slow and uncertain. Too much time may be lost between the opening of a stand for natural seeding and the beginning of active height growth by the new crop, especially where thinnings can be expected to defray planting costs within a relatively few years. Planting is the surest means of obtaining a pure and well-stocked stand, when and where it is needed.

It has been estimated that there are about 7 million acres of clear-cut, non-restocking longleaf pine lands, most of which must be planted if they are to be reforested satisfactorily in a reasonable period (289). Some 560,000 acres are in the national forests, including denuded areas, old fields, and patches of cut-over land remote from seed trees.

The feasibility of planting longleaf has been abundantly demonstrated.¹ Advantages in planting longleaf rather than some other pine are its resistance to fire, rust canker (*Cronartium*), tipmoth and other insect and animal pests, and its adaptability to a variety of sites. Tolerance of poor soil and capacity for early root development permit planting on sterile sites, if the soil is fairly stable.

Thousands of acres of longleaf land in Washington Parish, La., were planted in the late 1920's by a lumber company pioneering in forest planting. Their total costs, including collection and extraction of seed, nursery culture, lifting, packing, and transporting seedlings to the field, site preparation, and actual planting, ranged from \$3.42 per acre in 1925 to \$6.10 in 1927 (193). The splendid young forest that resulted served as an example to many other private interests. The company obtained pulpwood in 15 years and expects to obtain naval stores in 20, and sawlogs in 40 years (194).

In 1935 the U. S. Forest Service assumed a leading role in reforestation in the South, concentrating its efforts on longleaf pine lands.

SEEDS AND THEIR PROCUREMENT

Forest nurseries can succeed with longleaf only by paying close attention to the technical details involved in artificial propagation. They must often collect and process their own supplies of cones and seeds—an exacting procedure when properly handled.

Longleaf cones are from 4 to 12 inches long, usually not exceeding 10, and averaging 6 inches. Their diameter is from 1.6 to 2.7 inches, averaging 2. Young trees bear 60 to 80 cones to the bushel; old trees 100 to 120. A bushel of freshly collected, unopened cones weighs from 26 to 45 pounds. The cones open more slowly

¹Longleaf nursery stock is a trifle more expensive to produce than loblolly pine stock and 20 percent more expensive than slash pine. Nursery costs account for about half of planting costs. Longleaf seedlings are also more expensive to ship because they are larger and heavier than loblolly or slash pine. They have not survived as well as slash pine in eastern plantations.

than do those of any other southern pine and expand from 2 to $3\frac{1}{2}$ times in volume during the process. As the cones dry, the loss of moisture varies from 87 to 115 percent of dry weight, averaging about 105.

Deen (144) studied the relationship of weight to the germinative capacity of longleaf seed. As Table 32 shows, seeds weighed from 10 to 160 milligrams. The first 4 weight classes contained about one-fifth of the seeds, but none of these germinated. No gradual increase in germination with increasing weight of seed was manifest. High germination occurred in the heaviest classes, 85 to 160 milligrams, which included 70 percent of the entire lot. The results of this experiment indicate that worthless seed can be separated from the viable quite readily on the basis of weight.

Longleaf seeds are relatively large, with soft and leathery seed coats attached firmly to their wings. They germinate at low temperature, lose their vitality quickly in warm weather, but sprout promptly when sown.

Longleaf cones usually mature between October 1 and 20. Most fresh seeds with kernels are viable. Before gathering the seed, cones and seeds from several trees should be cut open to make sure that there are enough full seeds to be worth handling; then a test for ripeness should be applied. Cones must die a natural death on the trees before they can open normally and release their seeds. This is indicated by sudden loss in weight and reduction of specific gravity (to about 0.9) while the cones are on the tree.

Specific gravity, readily determined by immersing the cones in lubricating oil within 10 minutes of picking, can be used as an index to cone maturity. Unripe cones should not be picked. The correct time to collect cones is sometime after they die a natural death but before they open. Collection may begin when sound cones from 19 out of 20 trees float in oil (S.A.E. 20). When cones die prematurely from insects, disease, or poor handling, their dried scales are usually too rigid to open and release the seeds.

Wormy or diseased cones, pine needles, and trash should be removed in order to reduce costs of transportation and seed cleaning.² To extract seed successfully it is necessary not only to have sound cones, but also to provide good atmospheric conditions for drying them. Collected cones should be kept well ventilated, removed from sacks as promptly as possible, spread in shallow layers, and sheltered from rain to prevent molding and possible fermentation.

EXTRACTION OF SEED³

Extraction of seed at natural air temperature, under sheds or indoors, takes from 2 weeks to 3 months, requires more space, and may yield less seed per bushel than

²Through the contract system the Kisatchie National Forest has obtained cones delivered at central points for 25 to 30 cents per bushel (pre-war prices). Forest Service costs for clean seeds have ranged from 57 cents to \$1.33, with a 5-year average (1935-39) of \$1.11 per pound. Commercial dealers have usually listed longleaf pine seed at \$1.00 to \$3.50 per pound, occasionally as high as \$6.00 (pre-war prices). (Data from *Planting Quarterly*, Oct. 15, 1941, and catalogs on file at the Southern Forest Experiment Station.)

³Much of the information in this section was obtained from the Forest Tree Seed Manual, in preparation by the U. S. Forest Service, and other published and unpublished material supplied by P. C. Wakeley of the Southern Forest Experiment Station.

Table 32.—Distribution by weight classes of ½ pound of longleaf pine seed (144)

Weight class	Weight range	Seeds		Proportion of seeds
		Number	Percent	
1	10-25	16	0.6	
2	25-40	68	2.7	
3	40-55	204	8.0	
4	55-70	233	9.2	
5	70-85	240	9.5	
6	85-100	655	25.8	
7	100-115	803	31.6	
8	115-130	294	11.6	
9	130-145	21	.8	
10	145-160	4	.2	
Total		2,538	100.0	

does kiln extraction. Less work and simpler equipment are required, and possible injury to the seed by overheating is avoided. Direct solar heat is impracticable except for very small lots of cones because of the difficulty of protecting cones from dew and rain.

Precuring by 2 to 3 weeks of air drying in moderately shallow layers is advisable, if artificial heat is to be used in extraction. Precuring is a process designed to permit ripening of cones just short of complete maturity and to reduce the load of moisture to be removed by the kiln.

Kiln extraction is in some ways superior to other methods. Hadley demonstrated in 1925 that seed can be extracted in 16 hours or less without injury in lumber dry-kilns at 120° F. and 20- to 30-percent relative humidity. Exposure to high temperatures, however, may materially affect viability. One sample batch of longleaf

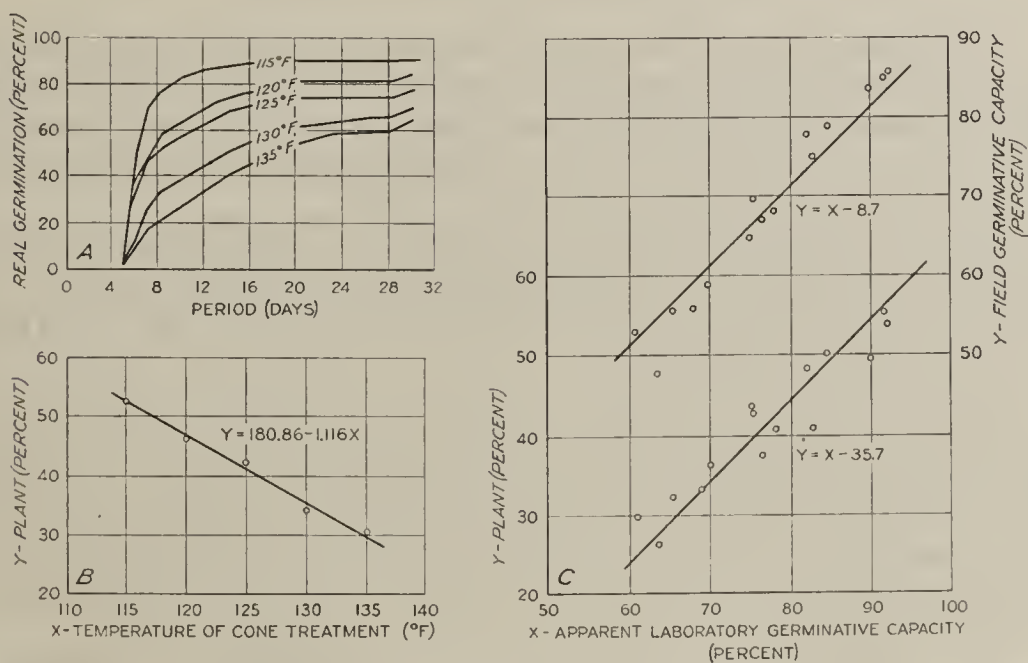


Figure 34.—Effect of high temperatures in kiln drying of longleaf cones (for the extraction of seed) on germination and quality of planting stock. A, germination; B, plantable seedlings; and C, relations of laboratory germinative capacity to seedlings sprouted and to those plantable (467).

pine seed extracted in outdoor racks at air temperature germinated 83.5 percent; another, from the same lot, extracted in a lumber kiln at 120° F. and 20-percent relative humidity, germinated about 75 percent; and a third, extracted at 140° F. and 10-percent relative humidity, germinated only 12 percent (594).

Longleaf seed, being very sensitive to heat treatment, is usually extracted in the kiln at 115° F.,⁴ sometimes at 120° F. After falling out of the cones, seeds should be in the kiln no more than 6 to 8 hours at 120° F.

Reasonably safe kiln-drying schedules for cones can be based on comprehensive studies made by Rietz (467, 468).⁵ Figure 34 and Table 33 show percentage of germination and production of plantable 1-year seedlings. The duration of cone treatment did not influence the number of utilizable 1-0 plants. Temperature, however, was highly influential, the lower temperatures being less injurious. Figure 34, B, indicates that for every 5° increase in kiln temperature, the number of plantable seedlings dropped 5.6 percent.

Table 33.—*Germination and plantable seedlings resulting from different kiln treatments of longleaf seed (After Rietz)*

Original kiln temperature (° F.)	Germinative capacity ¹				Utilizable 1-0 seedlings			
	Duration of original kiln temperature (hours)							
	8	12	16	Mean	8	12	16	Mean
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
115	90.6	92.6	92.7	92.0	49.5	55.1	53.6	52.7
120	87.8	86.4	85.6	86.6	50.2	48.4	40.8	46.5
125	80.9	79.7	80.9	80.5	42.8	43.8	40.7	42.4
130	79.7	71.3	69.3	73.4	37.3	33.3	32.3	34.3
135	72.7	66.6	62.5	67.3	36.3	26.5	29.9	30.9

¹Total germination by the 30th day. The mean percent of empty seed in each lot was 3.7. W. W. Ashe Extractory, De Soto National Forest, Miss.

The higher among the more moderate temperatures used in kiln experiments are particularly effective in increasing the rate at which cone moisture content is lowered. Moisture content of the seed at any given time is greater than that of cones (Fig. 35). Unlike some other pines, the lag in drying longleaf seeds may be ascribed to

⁴Any agency producing and handling about 5,000 bushels of cones per year can economically install a modern steam-heated forced-draft kiln (468). This type takes 6 to 10 hours to open cones, depending on moisture content, whereas a convection kiln requires 12 to 72 hours. Seeds are shaken out of cones in wire-mesh drums turning at 20 r.p.m. Opened cones exposed to moist air absorb enough water to close slightly and retain part of the seed; therefore, cones should be shaken promptly after removal from the kiln, or only on dry days if air-extracted. Incomplete opening of air-dried cones may reduce the seed yield to two-thirds that of kiln-dried cones.

⁵Rietz made 15 experimental runs using kiln temperatures of 115°, 120°, 125°, 130°, and 135° F. each for 8, 12, and 16 hours (467, 468), with the relative humidity adjusted so that all the runs were made at a 4-percent wood-equilibrium moisture-content condition. For instance, at 115° F. a 4-percent equilibrium was maintained with a 21-percent relative humidity, whereas at 135° F. a relative humidity of 24 percent was required. Increasing temperatures above 115° F., by intervals of 5°, reduced the viability of the seed proportionately. The correlation of the laboratory and field germinative capacities has the equation: $Y = X - 8.7$, where Y is the expected field germinative capacity when the laboratory germinative capacity is X. Similarly the correlation of laboratory germinative capacity and plant percentage has the equation: $Y = X - 35.7$, where Y is the expected plant percentage when the laboratory germinative capacity is X.

The mean difference between the laboratory tests and plant percentage was 35.7. This was caused by poorer field germination (8.7 percent), mortality during establishment and growing season (13.3 percent), and the rejection of cull seedlings in the fall (13.7 percent). Rietz states that these differences are not necessarily characteristic of the longleaf pine, and he points out that original kiln temperatures as high as 135° F. did not influence the mortality of seedlings once they had germinated.

their larger size. Because of this lag, the seeds do not dry enough during extraction materially to decrease their sensitiveness to heat. At 130° or 135° F., the shorter exposures were clearly less injurious than the longer ones. Drying at temperatures of about 115° (never over 125° F.) for 8 to 16 hours is a reasonably safe treatment, and superior to extraction at higher temperatures.

Both laboratory and field tests indicate that seed air dried to a moisture content of 35 percent prior to heating is slightly injured by a kiln temperature of 120° F. Hence fairly green or partly air-dried cones should be kiln dried at 115° F. and as low a relative humidity as can be obtained. The seed will then be suitable for sowing, although probably too moist for prolonged storage. Air-dried cones yield seed with a moisture content of 25 to 38 percent; kiln-extracted seed have 8 to 35 percent moisture, depending on type and operation of the kiln.

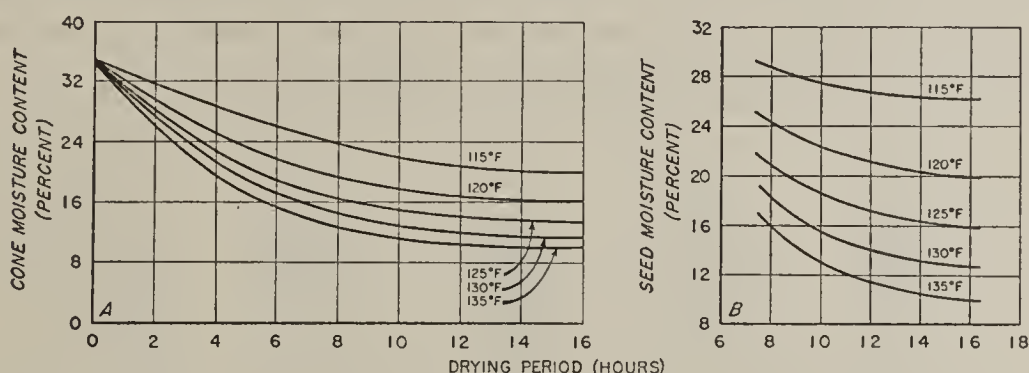


Figure 35.—*A*, moisture content of longleaf pine cones; and *B*, moisture content of seeds in relation to length of drying period and kiln temperature (467).

Because the wing is so firmly attached to the seed that mechanical removal is dangerous, longleaf seed is always sold and sown only partly dewinged. When dry, most of the wing may be broken off by running the seed through a rotary-brush dewinging apparatus. This simplifies broadcasting, permits drill-sowing by machine, and saves space in shipment and storage. Uncleaned longleaf seeds may be 20 percent empty, but wind winnowing and flotation are unsatisfactory methods of cleaning. Under good conditions, seeds with full or partial wings can be cleaned to a purity of 90 to 95 percent and soundness of 85 to 95 percent in an oscillating-screen, vertical-blast, seed-cleaning mill.

After extraction, the yields of seed cleaned in this manner are generally 0.5 to 1.2 pounds per bushel, with wings intact; with partial wings, 0.4 to 1.0 pound per bushel. Complete dewinging reduces the weight 10 to 15 percent, depending on moisture content; dewinging by machine reduces weight only 8 to 10 percent. At purity 100 percent, soundness 90 to 95 percent, and moisture content 15 percent, there are 3,800 to 6,000 winged seeds per pound, averaging 4,200; or 4,500 to 7,200 dewinged seeds per pound, averaging 5,000.⁶

⁶The cost of seed depends on quality. For example, at \$1.00 for 4,000 seeds per pound (pre-war prices), and with 10 to 70 plantable seedlings per 100 seeds sown, seeds cost 33 cents to \$2.50 per 1,000 trees produced.

GERMINATIVE CAPACITY

On slightly or moderately acid soil longleaf pine seeds germinate in the forest during November and December at mean daily temperatures of 50° to 55° F. (minima 35° to 45° and maxima 65° to 70°).

The most reliable procedure in testing germinative capacity is to germinate representative samples in the greenhouse or laboratory. This can be done most efficiently by a specialist working at some central point and using uniform methods. Under optimum nursery conditions, however, the germination percentage of fresh, uninjured seed approaches that of seed containing kernels. It is possible to estimate the percentage of full seeds by cutting a representative sample, or by crushing the seeds with a hammer and inspecting the crumbs. Quick tests of this kind are applicable only to fresh seed unimpaired by improper handling or storage. Heat killing during kiln extraction cannot be detected. At present a means of testing is needed that will be more precise and yet not require a month of actual germination. Chemical tests show some promise of filling this need.

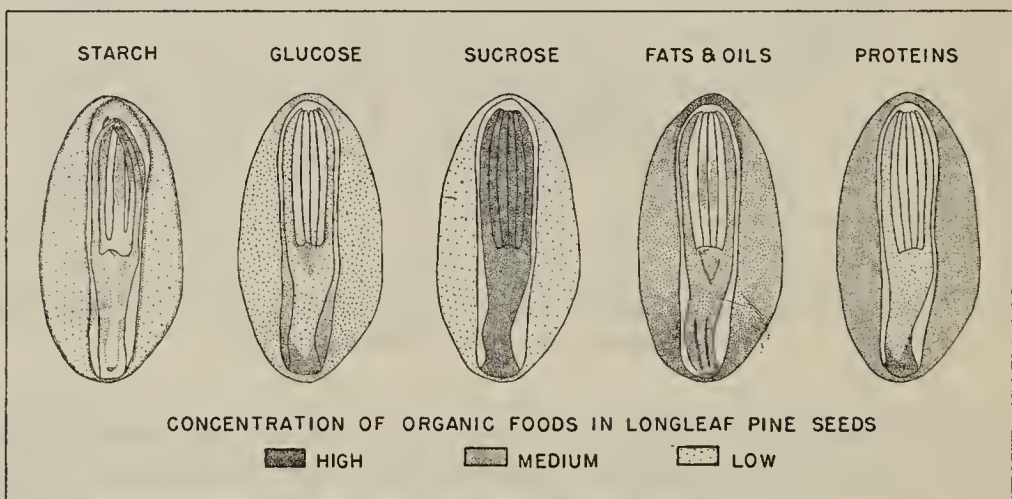


Figure 36.—The distribution of organic foods in fresh longleaf pine seeds. Shading indicates the concentration of certain foods in and around the embryo. (After Haas)

Various organic nutrients are found within and around the embryos, as shown in Figure 36. As the distribution of some of these or other substances may be related to germinative energy or capacity, some specific stain might be useful in distinguishing between the living and dead, or nearly dead, seeds.⁷

⁷Some successful but impractical attempts have been made to improve laboratory cutting tests by means of colorimetric or chemical reagents to spot the full kernels that are incapable of sprouting. To be acceptable, such short-cut techniques must be reasonably accurate and require less labor than the germination tests they are intended to replace.

Opportunities along this line, however, have by no means been fully explored. Tannins, for example and most of the foods shown in Figure 36, are more abundant in fresh than in old seeds. Certainly it is reasonable to expect that the chemical changes resulting from enzyme activity taking place between extraction and sowing may produce some end products peculiar to dead or hopelessly weakened seeds.

Recent work indicates that only traces of coniferin are present in viable seeds. A seed lot known to contain many dead kernels was stained with acid indicators. Concentrations of coniferin on longitudinal sections cut with a razor were revealed by concentrated sulphuric acid, which produced a violet color, and by hydrochloric acid or phenol, which produced a blue color. Haas, Anna, and Pessin, L. J. Chemical changes within longleaf pine seeds as an index of their germination. 1938. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

Longleaf seeds can be tested out-of-doors in winter if temperatures are favorable. If sowing is to take place in the middle of March, seeds may be tested in nursery beds the previous months in lots of 800 to 1,000 with the usual burlap-cover and screen protection.

In the laboratory, seeds are usually tested with sand flats, peat mats, or blotters as moisture-supplying media. Temperatures range from 60° to 80° F., although excellent field germination has occurred at 35° F. Above 80° F., germination is retarded or abnormal sprouting results, followed by failure to take root.⁸ Experiments have shown that germinative capacity drops suddenly in June and reaches a low in July and August, followed by gradual recovery with falling autumn temperatures (594). Under favorable conditions, a good indication of germinative capacity is obtainable in 20 to 25 days; and results of tests may be considered final after 30 to 40 days. With abnormal seed, 60 days may be required to reveal total germinative capacity.

Germinative energy is indicative of high germinative capacity (592). At the Stuart Nursery in central Louisiana it was found that longleaf seeds germinated in 12 to 20 days after sowing (310), and total germination varied with the rate of germination. In testing 10 species of conifers, Haasis (223) discovered that some, including longleaf, showed evidence of two optimum temperatures for germination. Germinative energy, as measured by the percentage sprouting in definite periods, was compared at constant temperatures ranging from 64° to 115° F. For periods up to 10 days, the optima for longleaf pine were below 64° F. and above 115° F. At these temperatures, and for all periods beyond the first day, 32 to 80 percent of the seeds germinated; at temperatures between 79° and 97° F., germination was less than 10 percent.⁹

Table 34.—*Germinative capacity of fresh longleaf pine seed pregerminated in moist acid peat at low temperatures, and comparable seed not pregerminated*¹

Pregermination period	Temperature	Final germination		Number of tests
		Pretreated	Untreated	
	° F.	Percent—		
30 days	41-45	70-77	51-75	2
36 days	37	72	56-66	2

¹From studies at Boyce Thompson Institute, Yonkers, N. Y., Southern Forest Experiment Station, and Brown Co., Berlin, N. H.

After drying or storage, longleaf seeds may become slightly dormant. This condition may often be corrected by a month of pregermination or "stratification" in moist peat, sterile sand, or well-weathered and chemically inert sawdust, at temperatures between 33° and 41° F. (35° to 38° preferred). This may increase germination, as shown in Table 34, unless the seeds have been injured in dewinging or other

⁸According to recent tests of 2 lots of seed, only 14 to 18 percent of normal germination may be expected at temperatures above 80° F., as against 49 to 64 percent between 65° and 75° F. McCulley, Robert D. Germination of longleaf pine seed at high and low temperatures. 1945. Jour. Forestry 43: 451-2.

⁹Recent work has failed to corroborate these results. Perhaps some of the seeds which Haasis listed as having sprouted under high temperatures should not have been recorded under germination. Some seeds of low vitality imbibe enough moisture to split open and protrude a nipple-like point. This could easily have been mistaken for actual germination.

ways. Premature sprouting of seeds that were stratified longer or at higher temperatures may lower the final results. Seeds devitalized by age occasionally may be revived to some extent by moist stratification for 30 to 45 days at 33° to 41° F.

Laboratory and nursery germination tests thus far have produced rather similar results, but the high percentage of ungerminated seed in both laboratory and nursery indicates the need for further research on internal seed condition as related to the process of germination (310).

Viability and Storage

Longleaf seeds are probably the most difficult of all pine seeds to store. Often, through improper handling, they lose half their viability 30 to 90 days after extraction, and all of it within a year.

Some of the same vital internal changes that lead to sprouting of fresh seeds may contribute to the perishability of stored seeds. Deferred sprouting is essential to the dormancy of seeds in storage or otherwise withheld from contact with mineral soil. For example, in the forest, damp weather may induce futile germination in partially opened cones on trees or the ground (383). Seeds may also germinate while suspended in grass or litter. Furthermore, the inferior response of longleaf to pre-sowing treatments (designed to break dormancy) may be explained by the energetic germination of fresh untreated seeds, whose dormant period is normally very short (23).

The difficulty of preserving longleaf seed for even 1 year led to an intensive study of its storage. Wakeley (593) found that the vitality of seeds could be maintained in cold storage for 1 or 2 years at 25° to 30° F. Barton (24) found that sealed cold storage at 5° to 23° F. was also effective, although by the end of 5 years production of seedlings had decreased to half the original amount. In general, it was found that storage temperatures need not be below freezing; in most tests, temperatures of 35° to 38° F. were low enough to maintain viability.

Some longleaf seeds have been kept successfully for 1 to 3 years in air-tight jars in a fairly cool basement, though there is a definite decline in viability. In one experiment, seeds showed no deterioration after 7 years of cold storage (405). In this case the record of the first 6 years in cold storage was somewhat marred by poor germinating conditions in the first and fourth years. Germination was high following cold storage, but failed completely after 2 years of storage at room temperatures (Table 35). Subsequent tests in this study produced about 60-percent germination in 34 days after 10 years of cold storage.

Reduction of moisture content helps preserve viability (404). Fresh longleaf seeds contain 8 to 38 percent moisture (based on dry weight), depending upon the method of extraction; seeds dissected from ripe but unopened cones contain about 41 percent moisture. In general, seeds from cones opened by air drying, or even in kilns, remain surprisingly moist. Tests showed that seeds stored at air temperature without extra drying were almost entirely spoiled in 1 year; but if dried under a fan after dipping in a fungicide and sealed in a glass jar, they were in excellent condition after

a year's storage at air temperature.¹⁰ Seed 77 percent viable, dried to 6-percent moisture content and stored for 10 months in sealed jars at room temperature, germinated 49 percent, and at 38° F., 66 percent. The same lot, with more than 10 percent moisture, germinated about 60 percent following cold storage, but failed completely when stored at room temperatures (Table 36). In another test, germination of seed

Table 35.—*Germination of longleaf pine seed kept in semisealed containers in cold storage and at room temperatures for various periods (404)*¹

Storage previous to test	Test period following storage		Proportion of seed germinated following storage	
	Variable room temperature	33°-55° F. cold storage	Variable room temperature	33°-55° F. cold storage
Months	Days	Days	Percent	Percent
0	30	—	59.2	—
8	55	54	25.5	27.5
9	55	51	25.0	52.5
10	55	49	37.5	70.0
11	50	42	43.5	77.5
12	45	31	26.0	65.5
13	60	38	26.8	67.6
Years				
0	50	50	55.6	55.6
1	45	45	8.8	41.2
2	—	—	—	—
3	—	46	—	61.6
4	—	70	0	26.0
5	67	67	0	48.0
6	80	80	0	46.0

¹A screw-top jar or can of seed for each test sample stored prevented any disturbance. The room-temperature storage in the early tests was in paper sacks in an unsealed and galvanized-iron can. About 200 to 250 seeds of each lot were tested by standard methods, without pre-sowing treatments other than storage. No attempt was made to measure or control atmospheric conditions in the laboratory. The significant contrasts are those shown for tests of viability after storage of 1 year or longer.

Table 36.—*Effect of moisture content on viability of longleaf pine seed held in sealed glass jars at room temperature and in cold storage (After Nelson)*

Initial moisture content (percent)	Germination ¹ after 10 months' storage at—	
	Room temperature	38° F.
	Percent	Percent
21.97	0	12.4 ²
17.85	0	34.8 ²
12.61	0	59.6 ²
9.50	0.8	56.8
6.02	48.8	66.4

¹Viability of seed before samples were dried and stored was 77.3 percent.

²Held in sealed jars at room temperature for 8 to 15 days before being placed in refrigerator, and therefore not strictly comparable with other seed lots.

stored at air temperatures in sealed containers for only 2½ months was as follows: 67-percent germination for seed with a 9-percent moisture content, and only 2-percent germination with a 22-percent moisture content.

It may be concluded that reduction in moisture content by methods not injurious to the seed (e.g., by air drying before a fan or in the sun) is distinctly beneficial in

¹⁰This result is attributed to the drying, not to the action of the fungicide. Longleaf pine seeds are practically devoid of fungi until the cones open and become heavily infected with mold spores which, however, do not ordinarily interfere with good germination. Nelson, M. L. Mold infection of southern pine seed in cones (1937-1939). U. S. Forest Service, Southern Forest Experiment Station. Office report. [Unpublished.]

maintaining viability; and that storage at low temperatures (approximately 30°-40° F.) also aids materially in preventing deterioration. To keep seeds viable for a year or more, low temperature and low moisture content are thus equally essential. With prompt extraction and correct storage, viability can be maintained at the original level for at least 2 years, and fairly well for 5 to 10 years.

Current recommendations are as follows: for storage of seeds from extraction until sowing in the ensuing February or March, a moisture content of 7 to 9 percent in unheated buildings is required. Any moisture content up to 20 percent at temperatures below 41° F. (preferably 35° to 40° F.) will suffice; or they may be kept both dry and cold. With 1 or more years of storage, a moisture content of 7 to 9 percent and temperature below 41° F. (preferably 35° to 40° F.) are essential. Seed stored at 38° F. in unsealed containers must be kept in an atmosphere of less than 40-percent relative humidity if the moisture content is to remain under 10 percent.

These recommendations have worked well in commercial practice. Seed stored under these conditions have remained viable for 10 years.¹¹

DIRECT SEEDING

Direct seeding in unprotected fields or denuded forests is less likely to succeed with longleaf than with associated pines.¹²

The persistence of wings probably helps birds to find longleaf pine seeds, thus reducing the chances of seeding.¹³ Natural seeding is most successful in years of bumper seed crops. On the other hand, artificial direct seeding may be successful in years when seed is scarce and birds are few (69).

Birds are not the only wild creatures that eat pine seeds. In one experiment in Mississippi less than 0.1 percent of unprotected longleaf seeds were unmolested, and on spots screened against birds only 10 percent developed into seedlings; on spots screened against mice and birds, 70 percent developed into seedlings. In a Florida test, trapping or poisoning of rodents was necessary in preparing sites for direct seeding.

Despite these difficulties, some unusual success has been recorded with direct seeding. In one case (597), 6 to 12 seeds per spot were sown in December 1931 and January 1932 in shallow drills in a recently abandoned corn field of 100 acres in Georgia. Several methods of covering the seeds succeeded; the only test which failed was broadcast sowing. Doves took far more seeds than rodents. The spots were thinned, as in chopping cotton, and in 8 years a perfect stand of longleaf pine 12 feet high developed. Successful direct seeding has also been reported from South Carolina (472), where the sowing of some 10 or 12 seeds per spot in 1900 yielded an annual increment from longleaf growing stock of \$3 per acre after 40 years (Table 37).

¹¹A Georgia nurseryman has kept seeds for 2 years by drying them in the sun in sacks 2 or 3 days a week, from extraction in November until March, then transferring them to clean grease cans, screwing the tops on securely, and depositing in pecan cold-storage warehouses.

¹²Experiments have shown that the principal southern pines are increasingly amenable to direct seeding in the following order: longleaf, slash, loblolly, and shortleaf. The size of seed of these species decreases in the same order.

¹³The first rain after seed fall washes the seeds of other pines free from their wings, thus helping them to penetrate thick grass and be less conspicuous to birds.

On 16 areas aggregating several thousand acres direct seeding of longleaf pine from 1911 to 1937 was 6 percent successful, 38 percent partially successful, and 56 percent failure. Birds, rodents, and ants were the chief causes of failure. Seeding costs on fully half of the successful areas were exorbitant, being often several times that of planting stock. Thus, heavy application of seed and thorough preparation of the site sometimes produced the stands desired, but only at a sacrifice of the original objective—low cost.

Table 37.—*Estimated financial yield of a 40-year-old longleaf pine stand grown from seeds sown in spots on deep Norfolk sand in Lee County, S. C.*¹ (472)

Products available for harvest	Per acre in 40 years	Per acre per year
	<i>Dollars</i>	<i>Dollars</i>
Pulpwood, 38.26 cords per acre	38.26	0.96
Poles, 70 per acre	43.47	1.09
Poles plus pulpwood	69.57	1.74
Saw timber (15,652 bd. ft. per acre)	108.70	2.72
Poles plus saw timber	121.74	3.04
Poles plus loblolly pine (volunteer associates)	130.43	3.26

¹Trees were spaced approximately 10 by 10 feet. Pulpwood stumpage was estimated at \$1.25 per unit or \$1 per cord, and sawlogs at \$7 per M board feet. Poor soil and the continuous removal of pine straw lowered the yield.

NURSERY PRACTICE

In recent years, most longleaf pine nursery stock has been grown as 1-year-old seedlings in the Ashe Nursery near Brooklyn, Miss., and the Stuart Nursery near Pollock, La., both operated by the U. S. Forest Service.¹⁴ Together they produced an average of 43 million seedlings annually from 1936 to 1940, of which about 70 percent was longleaf pine.

The following schedule approximates the sequence of nursery operations throughout the year:

February and March—Plowing and harrowing as early as soil and weather permit. Excavate paths, and shape, level, and thoroughly pulverize seedbeds.

Early March—Sowing of seeds (by mechanical seeder¹⁵ or broadcast). After hand-sowing, the beds are pressed with a 400-pound roller of large diameter. Seedbeds are protected with fabric or natural mulch covering, such as pine needles, and kept moist and unmolested by birds.

Late March or early April—Removal of the fabric or mulch. Seedbeds are weeded (by hand). Watering. Damage by birds, cutworms, or damping-off is carefully controlled.

Late April—Weeding and protection continued as needed.

May—Second or third hand weeding and sprinkling as needed.

June—Third or fourth weeding, regular sprinkling, and possibly first spraying for brown spot. About 3 to 6 summer sprayings are needed.

¹⁴They are equipped with good water supplies and overhead sprinklers, and utilize terraces to avoid loss of soil in erosion, and cover-crops together with fertilizers to maintain soil productivity. Many operations are mechanized, particularly the lifting of seedlings from seedbeds, and spraying (124, 308).

¹⁵Retention of parts of the seed wings of longleaf pine often clogs the machinery. In mechanical seeding the seeds are fed between the wide spiral flanges of carpenters' bits from the hopper and into drill-sowing tubes. The spiral feeds are geared to a revolving rod actuated by the wheels of the seeder.

July to October—Continued weeding, control of insects and disease, and watering, especially during drought. It is preferable to discontinue watering early in September.

November to January (after the close of the growing season)—Spraying, lifting, grading, and packing of seedlings for shipment. The final spray protects the seedlings during the first 6 months in the field.

Sowing in the fall or early winter is coming into increasing favor, although this may produce yearling seedlings susceptible to damage from frost-heaving—and possibly hail—in the nursery 1 or 2 months after sowing (Table 38). Moreover, some 14 months later, seedlings in beds of subnormal density may become too large for effective field planting. If spring-sown beds are subject to serious losses from damping-off fungi, fall sowing may be preferable.

Nursery seedbeds may be covered with pine straw or burlap, but present practice favors cotton fabric. Newly germinated longleaf pines can seldom push their way through burlap because of short stems and thick cotyledons.

Seeds germinate and survive in unshaded beds as well as or better than in shaded beds. In the shade, seedlings tend to increase in height, sometimes with an appreciable loss of plantability. Unshaded seedlings are stouter and heavier than shaded ones.

Table 38.—*Germinative capacity and size of 1-0 longleaf stock in nurseries at Bogalusa, La., by date of sowing*¹

Date of sowing	Total germination	Final tree production ²	Average length ³	
			Needles	Roots
	Percent	Percent	Inches	Inches
Nov. 13, 1924	86.4	61.8	16.2	23.3
Dec. 15, 1924	84.2	70.2	15.2	20.6
Jan. 17, 1925	78.4	64.6	15.2	20.0
Feb. 13, 1925	76.2	69.8	11.5	19.2
Mar. 12, 1925	72.4	56.6	7.8	16.8
Apr. 18, 1925	10.4	2.8	7.2	17.2

¹Seed was covered with sand to a depth of from 1⁄8 to 1⁄4 inch.

²In percent of seeds sown.

³At the end of the growing season.

An attempt has been made to determine normal seedling environments in nursery beds, normal growth rates, and normal development of longleaf seedlings (310). The accretion of top and root weight following sowing on March 11 is shown in Table 39 from experience at the Stuart Nursery. Forty-six percent of the seeds germinated. About 35 percent of the seeds planted developed into live seedlings. After thinning and culling, there was a net total, from the original sowing, of 12 percent plantable seedlings.¹⁶ Stages in the normal development of nursery stock are illustrated in Figure 37, and the cumulative growth of tops and roots in 6½ to 10 months after spring sowing, together with the approximate emergence of buds and other vegetative developments, in Figure 38.

¹⁶In this experiment the seedbed was purposely oversown and then thinned to insure uniformity of stand. In normal practice, the sowing rate would have been reduced and the final proportion of plantable 1-0 seedlings would have approximated 15 percent.

Table 39.—Dry weight of tops and roots of longleaf seedlings excavated from seedbeds at stated intervals during their first year, Stuart Nursery, La.¹ (310)

Period after sowing— (days)	Top weight		Root weight	
	Mean	Standard deviation	Mean	Standard deviation
	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>
20	0.03	± 0	0.01	± 0
42	.07	±0.02	.03	±0.01
63	.17	± .03	.08	± .03
84	.41	± .08	.20	± .05
105	.73	± .24	.32	± .09
126	1.03	± .45	.36	± .10
154	1.41	± .43	.57	± .17
182	1.76	± .73	.75	± .29
210	2.23	± .78	.86	± .47
238	2.36	± .81	.96	± .43
266	2.77	±1.08	1.26	± .44
310	5.03	±2.25	3.33	±1.91

¹Solar radiation was high; mean air temperature ranged from 47° to 83° F.; soil temperature at the surface averaged 55° to 89° F.; mean relative humidity averaged above 60 percent; and annual precipitation was more than 40 inches. Soil moisture, supplemented by sprinkling, remained above 10 percent during the growing season.

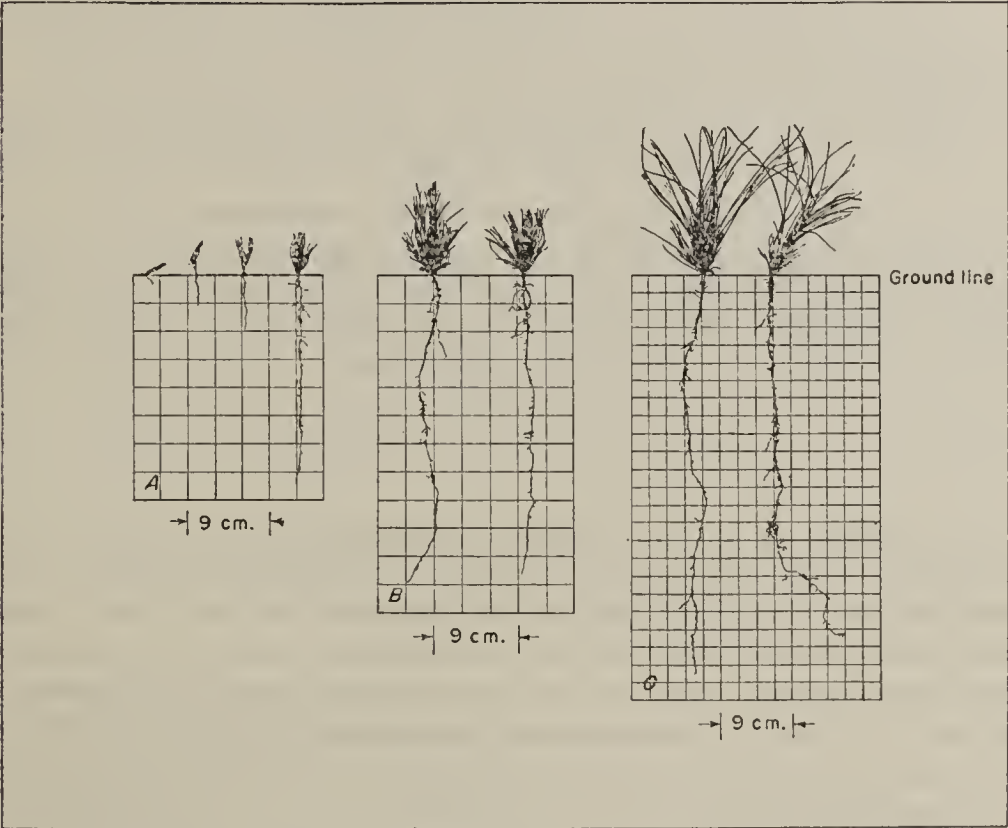


Figure 37.—Development of longleaf pine seedlings in nursery beds. A, seedlings just after burlap was removed, in cotyledon stage (before and after shedding seed coat), and at beginning of primary-needle stage; B, seedlings at 84 days, showing primary needles; and C, at 184 days, with prominent secondary needles and thicker root collars. (After Huberman)

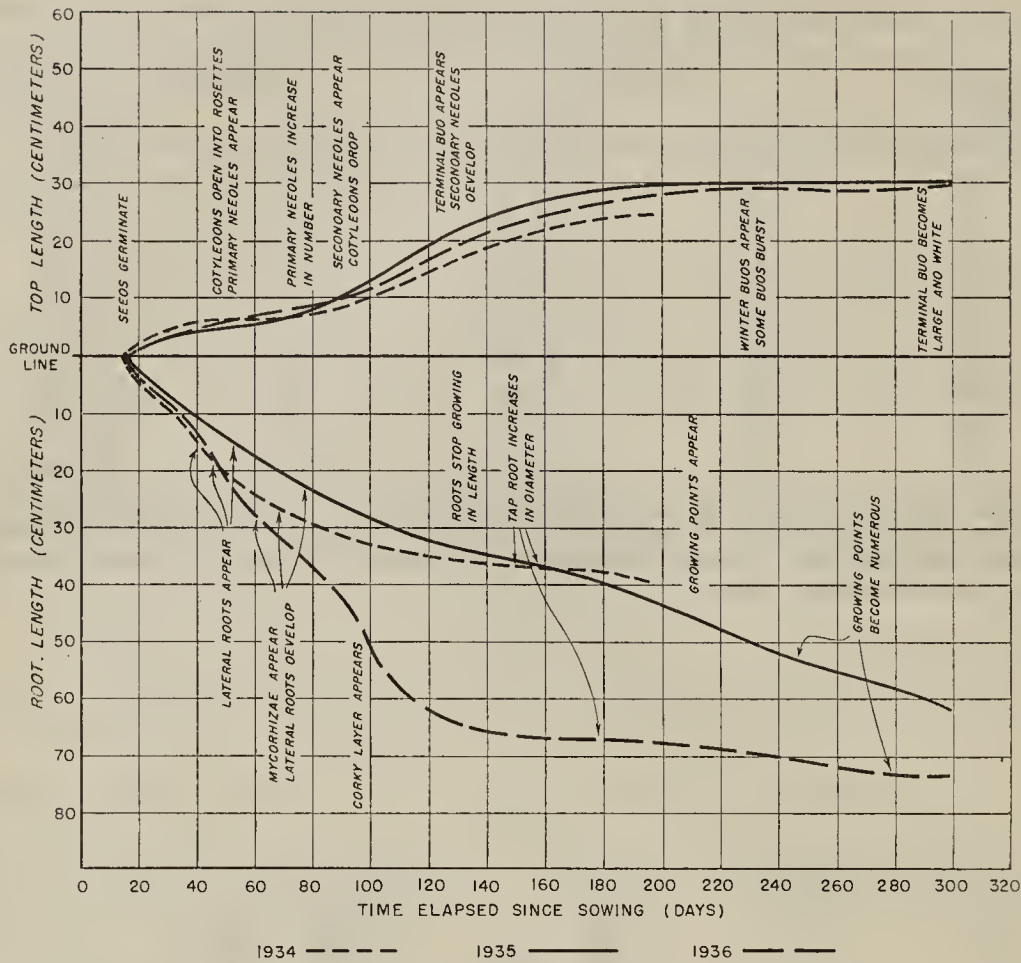


Figure 38.—Normal cumulative growth of tops and roots of longleaf pine seedlings in nursery beds, measured to tips of needles. Curves show rates of elongation above and below ground in 6½ to 10 months after sowing. Arrows indicate dimensions and time when definite anatomical developments became apparent. (After Huberman)

In nursery beds the number of longleaf seedlings should not exceed 20 to 40 per square foot if seeds are broadcast, or 10 to 18 per linear foot, if sown in drills 6 inches apart; the lower figures are the most desirable if the soil is low in fertility. Overstocking or understocking increases the percentage of culls. The higher densities yield more plantable trees, but the lower densities develop thicker stems and longer roots. The yield of top-grade seedlings increases at densities slightly below the optimum, but extremely thin stands are likely to produce rather poor seedlings.

Thin stands yield the best but most expensive trees, while understocking greatly augments the costs of weeding, watering, spraying, and lifting. Rates of sowing may range from 3.5 to 12 pounds of seed per 4- by 100-foot bed, depending on seed quality. For instance, seeds yielding a plantable percent of 27.7 and numbering 5,200 per pound should be sown at the rate of 16 ounces per 4- by 12-foot bed to

provide about 100 seeds and 25 to 35 seedlings per square foot broadcast, or 45 seeds and 12 to 18 seedlings per linear foot sown in drills (309).¹⁷

Seeds are rolled into freshly prepared soil and covered with 10-ounce, coarse-woven cotton cloth, 7- to 10-ounce burlap, or occasionally an inch of pine needles. Mulch coverings are usually removed in 10 to 25 days, when germination is nearly complete. During the colder months germination is delayed, and mulch is retained up to 35 days. Seedlings need protection from birds for 6 to 9 weeks after sowing. In the cotyledon stage longleaf pine is especially susceptible to patchy thinning by damping-off diseases. Some 2 to 6 sprayings with Bordeaux 3-3-50 mixture between June 1 and December 30 generally control brown spot. It is advantageous to use a commercial spreader or sticker in this mixture at the rate of 2 to 3 ounces or $\frac{1}{2}$ to 1 pint per 100 gallons, according to the type of applicator used. While the number of seedlings suitable for planting is decreased by thinning, the green weight and the percentage plantable are increased.¹⁸ Huberman (311) found that root pruning in place during June or August increased the plantable percentage significantly, but many root systems assumed forms difficult to handle in the field.

Soil fertility as well as stand density is of prime importance in controlling root systems without pruning until they are cut to 7 or 8 inches for field planting. Likewise, soil amendments are indispensable in the intensive culture of a crop of which both tops and roots are harvested annually.

The effects of seedbed fertility and plant density were studied by Muntz (402). Compost was made from rice straw by adding a reagent composed of 45 percent ammonium sulphate, 32 percent finely ground limestone and 23 percent rock phosphate ground to pass a 200-mesh sieve. One hundred and fifty pounds of this mixture, plus 500 gallons of water, were added to a ton (dry weight) of rice straw. Watered currently to keep it moist, the pile was left undisturbed for 8 to 10 months and yielded 3 tons of compost per ton of straw. This compost was applied in 0-, 1-, 2-, and 3-inch layers (subsequently mixed in soil) to longleaf seedbeds later sown with different amounts of seed. Stands ranging from 10 to 50 seedlings per square foot resulted. Figure 39 shows the effect of compost and growing space on the length of needles, diameter of stems, length of root, and green weight. A 1-inch layer of compost, equivalent to about 23 tons of dry weight per acre, was as effective as

¹⁷In estimating seed requirements for sowing nursery beds, the following formulae are useful:

$$w = \frac{a \cdot s}{c \cdot p \cdot g \cdot l} \quad \text{or} \quad w = \frac{a \cdot s}{u \cdot g \cdot l}$$

where

- w = pounds of seed per bed
- a = area of bed in square feet
- s = number of trees desired per square foot at end of year
- c = number of clean seeds per pound
- u = number of uncleared seeds per pound (material on hand)
- p = purity percent
- g = germination percent
- l = percent of germinating seedlings expected to live

(p, g, and l are expressed as decimals)

When c and p are unknown, the second formula may be used to approximate the result of the first formula.

¹⁸Muntz, H. H. A study of various combinations of sprinkler-watering and cultivation. 1940. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

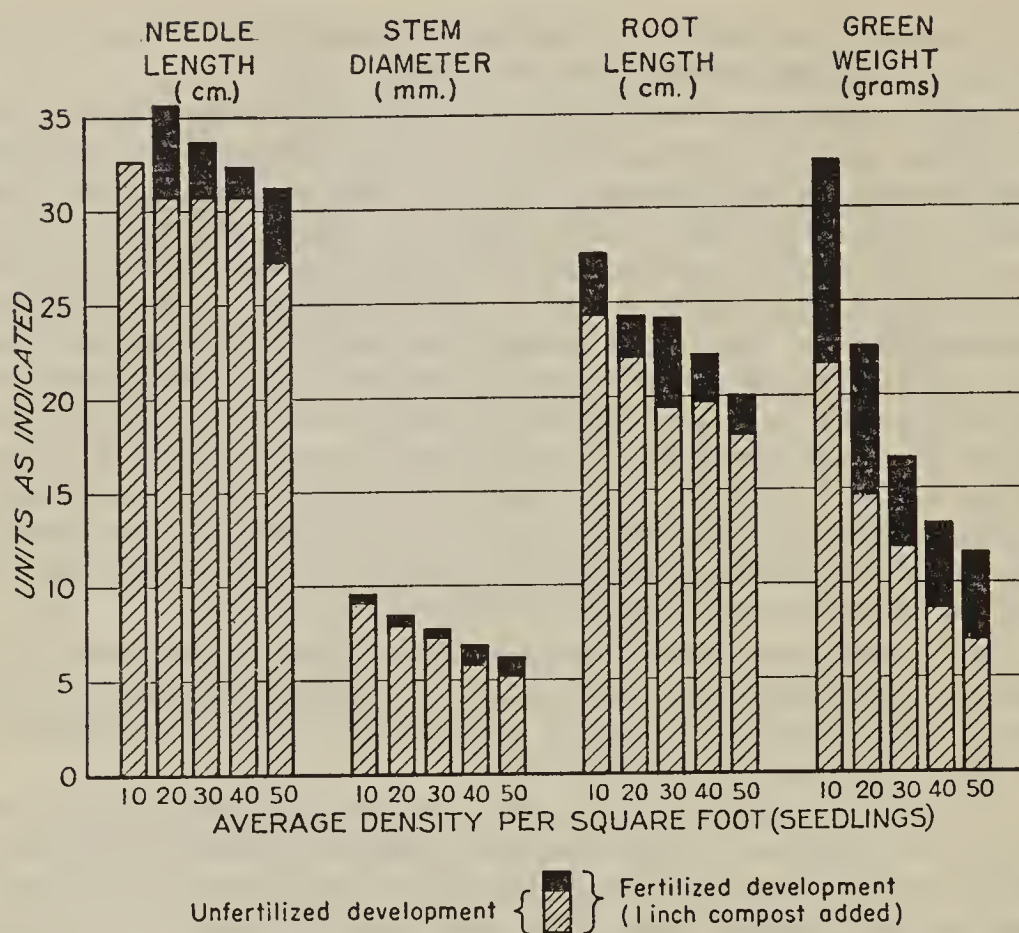


Figure 39.—Development of 1-year-old longleaf seedlings in nursery beds in relation to density of stand and application of compost. (After Muntz)

heavier applications.¹⁹ Improvement in the seedlings was ascribed to better structure, aeration, and moisture conditions in the soil, as well as to increased plant nutrients, especially nitrogen, which normally accompany any addition of organic matter.²⁰

Compared with untreated seedbeds and stock, the fertilized beds and seedlings presented the following difficulties: (1) lower germination of seeds and greater loss in establishment from superficial drought; (2) more weed seeds, and therefore more numerous and thrifty weeds; (3) unhealthy color (chlorosis) in some of the pines (corrected, in this instance, with 1-percent ferrous sulphate spray); and (4) crooked taproots resulting from concentration of compost that was not thoroughly decomposed. On the other hand, loose friable soil facilitated lifting of seedlings, with less

¹⁹This experiment, plus observations of later commercial applications of compost in forest nurseries, shows that the treatments tested were too heavy, and that a better test would have been with applications in 0-, 1/3-, 2/3-, and 1-inch layers. The optimum treatment might have been a layer of compost 1/3 to 2/3 inch thick.

²⁰The amount of nutrient added by raising green manure crops in nurseries is considered adequate only to maintain existing fertility. Supplementary fertilizers such as well-rotted compost appreciably increase soil fertility. An advanced stage of decomposition is desirable not only to yield the most readily available plant food, but also to facilitate proper mixing with soil. Commercial inorganic fertilizers can be most advantageously applied to stimulate the growth of green manure crops grown in alternation with the pines.

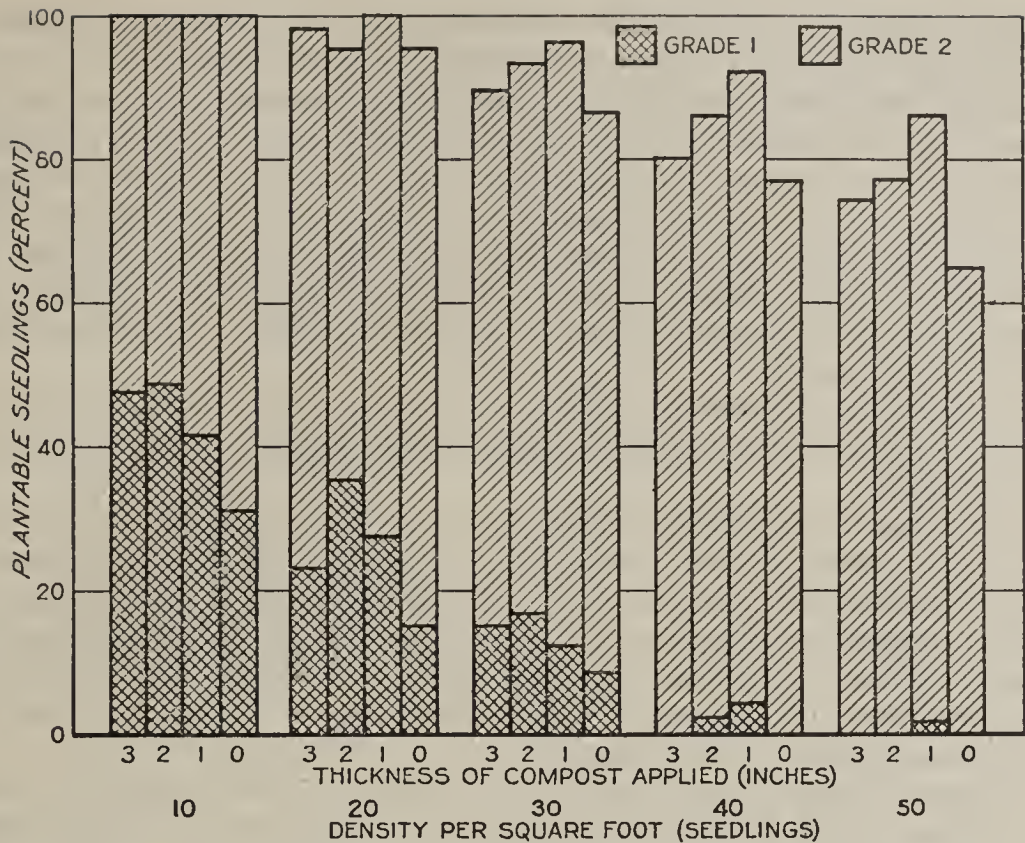


Figure 40.—Plantable 1-year-old longleaf pine seedling stock as influenced by various depths of compost fertilization. (After Muntz)

breakage of rootlets, so that a larger portion of the natural absorbing root surface could be planted.

The size, grade, and plantable percentage of longleaf seedlings decreased as density rose from 10 to 50 plants per square foot. Figure 40 shows plantable percentage by grades of stock at the end of the first season. Where the maximum number of plantable trees per pound of seed was sought, the lowest density was best, but where the maximum per unit of seedbed area was desired, the highest density was best. On the whole, seedlings at a density of 10 trees per square foot were somewhat too large, and those at 50 trees per square foot too small. An average plant of most desirable size and balance (top-root ratio) was grown at the rate of 30 seedlings per square foot. This optimum density may be increased if higher levels of fertility are maintained.

PLANTING

The first successful commercial plantation of longleaf pine was established in 1924. Since then it has been amply proven that the species can be planted with skillful handling almost as cheaply and effectively as other pines.²¹ Indeed, high-

²¹Longleaf seedlings, because of their lack of stems as well as greater size, are more difficult to pack in bales and ship to planting sites than are other southern pines. They are baled with roots turned inward, kept moist with sphagnum moss. Some 1,200 trees are compressed into a bale bound with metal straps.

quality longleaf pine nursery stock is first among southern pines in adaptation to different sites and ability to endure unfavorable forest conditions.

In the southeastern portion of the longleaf belt, however, it has so far been almost impossible to obtain early height growth or satisfactory survival in plantations. Likewise, in northeastern Florida, southern Georgia, and southeastern Alabama, many plantations not only fail to begin height growth in their third to tenth years, but are understocked because of losses from brown spot, vegetative competition, and other causes in the first decade after planting. On the other hand, other pines, particularly slash, have survived planting very well on these sites in the absence of rust-canker infection and fire.

Successful forest planting requires stock of suitable size and high quality, derived from proper seed and carefully handled in the nursery. As S. A. Wilde has remarked (605):

"The characteristics which seedlings acquire in the period of their early development in the nursery are often transmitted to plantations. If the planting stock is grown in an unsuitable environment, if it is underdeveloped or overdeveloped, injured by chemicals or infested with parasitic organisms, one of two results may be expected. Either the seedlings will die immediately after being transplanted, or—what is even more unfortunate—they may struggle on for a number of years and finally be destroyed by fungi or insects."

Longleaf is usually conspicuous for good growth in planted stands as contrasted with self-sown stands. Planted longleaf often begins height growth promptly, largely because of the superior development of seedlings in the nursery. Top-grade, nursery-grown stock 10 months old is as large as an ordinary 3- to 5-year-old seedling grown naturally under good conditions. Beginning active height growth in their third year in the field, plantations frequently outstrip natural stands of the same age.²² In addition to benefits obtained in the nursery, the relatively wide spacing in plantations helps to prevent the spread of brown spot (Pl. 25).

Often there is no site preparation beyond clear cutting and burning, but scalping of planting spots is sometimes advantageous. The control of competing vegetation and injurious agents is usually postponed until after planting. Clearing grass from spots 12 to 15 inches square with heavy hoes before planting is more satisfactory than plowing furrows. The spots should be hoed during the summer, so that loose soil will be washed in by fall rains and reach a permanent level before the planting season. Seedlings properly set in such spots suffer little or no damage from silting. On some soils, burning the surface vegetation before planting increases sheet erosion and adds to the danger of silting injury to the nearly stemless seedlings. When longleaf seedlings are planted on level unburned sites or in properly prepared spots, silting-in or burying of the plants by rain-washed soil seldom occurs.

The use of wild seedlings in place of planting stock is not recommended. In general, wild stock is expensive to handle, and survival and growth are uncertain.

²²The most remarkable plantation so far noted is in St. Tammany Parish, La., where the trees reached an average height of 10 feet at 5 years from seed. The largest tree at that age was 16 feet high and 3 inches d.b.h. This stand was not fertilized and received no special care after planting except one or two sprayings for brown spot. A heavy mulch of pine needles was allowed to rot around each tree. The soil, however, had been fertilized and thrown up into ridges while under previous cultivation.

Nursery seedlings are usually lifted from the seedbeds as 1-year-old or "1-0" stock when 9 to 15 months old. The poorest are culled out. High grade seedlings must be free from disease. Longleaf seedling grades were originally described by Wakeley in 1935 as follows, with some overlapping of size classes:

<i>Grade</i>	<i>Stem</i>
1	Usually 3/16- to 1/2-inch diameter at ground surface.
2	Diameter at ground surface usually intermediate between those of grades 1 and 3.
3	Very slender at ground surface (no maximum diameter).
	<i>Needle Length</i>
1	10 to 18 inches.
2	Intermediate between those of grades 1 and 3.
3	6 to 8 inches.
	<i>Foliage</i>
1	Abundant, largely or entirely fascicled.
2	Intermediate, always some in fascicles.
3	Scanty, frequently with none in fascicles.
	<i>Winter Buds</i>
1	Scales usually abundant.
2	Scales usually lacking; naked buds abundant.
3	Absent.
	<i>Taproot</i>
1	Stout—3/16 to 1/2 inch at ground surface.
2	Intermediate.
3	Slender.
	<i>Dormancy</i>
1	Usually completely dormant.
2	In Gulf States, dormancy depends on weather conditions.
3	Rarely dormant in Gulf States.

Later, Huberman (309) stated that seedlings less than 3/16 inch thick at the ground line should be culled; when a landowner or manager, planting on a small scale, sorts his own seedlings, he can improve the results by culling more flexibly (Fig. 41).

High-grade longleaf seedlings not only suffer less from brown spot and silting, but also begin height growth at an earlier age than do low-grade seedlings. Indeed, as already noted, grade-1 stock planted properly grows far faster than do the best natural stands. Wakeley found that in one plantation survival of grade-1 stock after 4 years in the field was 82 percent and that of grade 3 only 49 percent. Grade-1 seedlings also grew better than grade 3; 22 out of 200 grade-1 trees were 6 inches or taller, while of grade 3 only 3 out of 112 were 6 inches tall and none exceeded that height. Obviously, grade-3 seedlings should not be planted in the field. Grade 2 is unsatisfactory on adverse sites, but present culling practices—based on a rigid diameter limit of 3/16 inch and a fixed requirement of secondary needles—eliminate only part of the grade-2 stock as described by Wakeley.

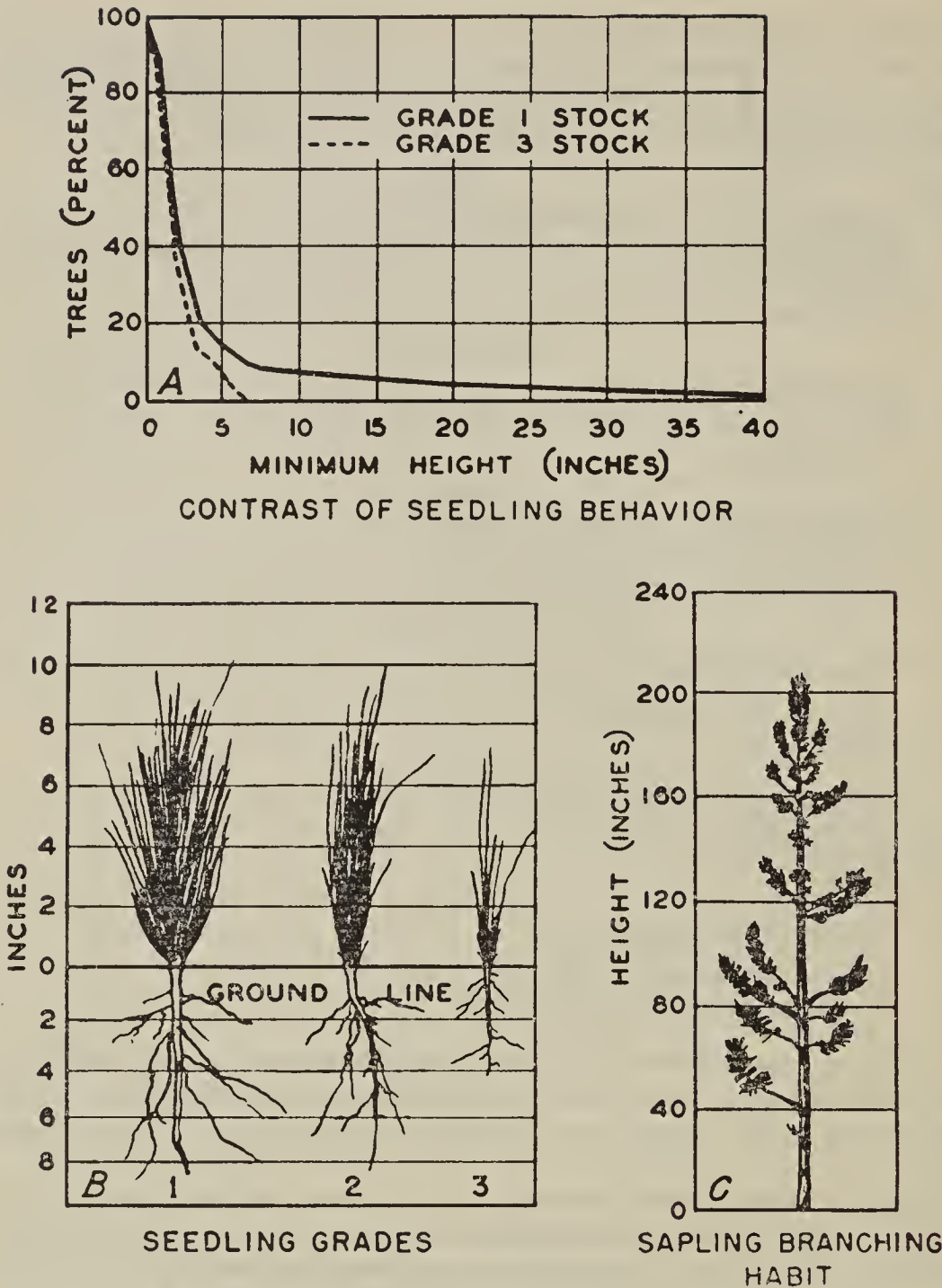


Figure 41.—Growth of grades 1, 2, and 3 longleaf pine planting stock. *A* shows superiority in height of grade 1 over grade 3 in plantations; *B*, the average size of 3 grades of nursery stock; and *C*, the branching habit typical of saplings.

In many localities brown-spot infection does not affect longleaf plantations. If kept free from fungus in the nursery, high-grade stock makes such a vigorous start that infection during the first year or two in the field does not prevent emergence from the grass. Above about 18 inches in height, the danger from brown spot is

usually negligible. Where the disease is severe and seedling growth naturally poor, brown spot must be artificially controlled or it may cause high mortality and delay the height growth of surviving trees for many years (594). Even severely diseased plantations, however, should not be burned over until after their second growing season.

The spacing of trees in plantations depends on the survival expected and on economic considerations, such as costs of establishment, major products, market for thinnings, and effects of stand density and crown differentiation on natural pruning of the stems. The tendency has been to space too widely. Six by 6 feet is now gen-

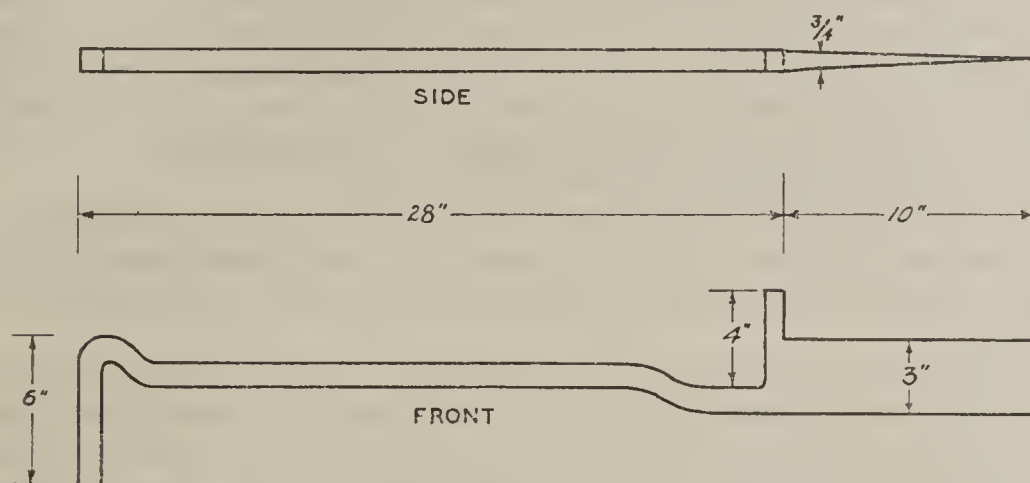


Figure 42.—Planting iron used in the South for all pine species.

erally recommended, and $5\frac{1}{2}$ by $5\frac{1}{2}$ feet is considered advisable where pulpwood thinnings can be made. In the closer spacings, one row may occasionally be omitted in order to provide a lane for motor trucks. If longleaf and slash pine are planted for timber production without thinnings, the trees should be spaced 6 by 8, 7 by 7, or 8 by 8 feet. If timber and pulpwood production is sought, spacings of 6 by 6 or 6 by 8 feet may be used. For naval stores, spacings of 10 by 10 or 12 by 12 feet are suggested.

From 1,200 to 1,400 seedlings per man-day can be planted with the conventional planting iron (Fig. 42). A 17-inch pistol-grip dibble has been designed to facilitate planting on the deep sands and brushy areas in western Florida (200).

Longleaf pine survives better than slash pine on ridge land, but takes longer to get under way. Hence, in longleaf plantations, spots which have failed may sometimes be replaced with slash after 3 or 4 years. In this event, longleaf has a nearly even start with the slash pine and ordinarily will not be badly overtopped by it, unless the site is much better adapted to the latter species.

Fire appears to retard the height growth of longleaf less than that of slash. Furthermore, longleaf, growing in mixture with slash pine or some other less fire-resistant species, provides insurance against complete destruction of the stand in an accidental fire.

SUMMARY

When natural regeneration of longleaf pine forests fails, artificial means are available.

Maturity of cones is tested by immersing a representative sample in lubricating oil (S.A.E. 20) within 10 minutes of picking. If the cones sink, the crop is not ripe enough to pick. Curing in sheds takes 2 weeks to 3 months. When immediate sowing is contemplated, partly air-dried cones may be kiln dried at 115° F. and at as low a humidity as can be obtained. The number of seeds per pound ranges from 3,800 to 7,200, averaging 4,200 with wings or 5,000 dewinged. Cleaning in an air-blast cleaner is advisable, and testing for germination may be accomplished in 3 to 4 weeks. Seeds deteriorate rapidly when stored in warm, damp places, but if kept dry (about 8 percent moisture) they may retain viability for 2 years even at air temperature, though with impaired vitality after the first 6 months. Storage at 7- to 9-percent moisture content and 35° to 40° F. is effective in preserving vitality. Some lots stored in this manner have remained viable for 10 years.

Direct sowing in the field or forest is less likely to succeed with longleaf than with other southern pines. Thorough preparation of seed spots, sowing of ample seeds, and ingenuity in outwitting predators may bring success, but usually at exorbitant cost.

Greater success may be expected from planting 1-year-old longleaf stock grown in nurseries, where the plants are not only protected from birds, rodents, insects, hogs, and fire during the stages in which they are most vulnerable, but need not contend with hard, dry, or sterile soil, or disease, overcrowding, or weeds. Also, in the nursery, longleaf seedlings do not need protection from the sun; in fact, they become stouter and heavier when unshaded. Successful planting requires suitable size, high quality, and careful handling of nursery stock.

Part 4. PROTECTION

VIII. Protection From Fire

THE FOREST FIRE SITUATION

THE SOUTH has long held first place among all regions of the United States in indiscriminate woods burning. In the deep South fires have been more numerous and less devastating than elsewhere in the United States. The longleaf pine belt has sustained more frequent and widespread burning than any other part of the region.

During the 5-year period 1939 to 1943, inclusive, about 15 percent of the forested area in 8 southern States was burned each year. In North Carolina the annual burn covered an average of 3 percent of the forested area; in Texas and Louisiana, 5 percent; Alabama, 8 percent; South Carolina, 10 percent; Georgia, 15 percent; Mississippi, 27 percent; and Florida, 38 percent. The prevalence of the longleaf pine type partly accounts for Florida's high figure. Normally, however, a larger proportion of the area in the longleaf type is burned in Mississippi and Louisiana than in Florida. About 23 percent of the total forest area needing protection and 64 percent of the Nation's forest fires were in the 8 southern States in 1939-43.

Ostensibly this paints an extremely dark picture of the risks in southern forestry, but fire statistics must be interpreted in the light of conditions peculiar to the longleaf region. Untenable comparisons with northern conditions have often led to exaggeration of fire risks in the South (108) (Pls. 26, 27, and 28).

An element of the rural population in the South has burned the woods at will from time immemorial. Some persons have sought retaliation or other emotional release, but most were seeking free range improvement by this traditional means. A dogmatic attempt on the part of land managers to prevent woods burning has seldom proved successful over a long period. The need for an effective educational program is evident, but so is the need of the rural population for a square deal in meeting its economic problems.

Local residents have been responsible for most of the woods burning. After the virgin timber was cut, landowners usually exercised no control over their timberlands. Those not interested in forestry were tolerating, or even encouraging, annual burning in the hope of being able to sell their land for farms, though actually little of it was ever cultivated. Burning during winter and spring to destroy pests, improve range, and for other reasons is still common. The peak of burning usually coincides not with "fire weather," but with intentional burning habits of long standing (61).

In the longleaf belt some land is still burned to protect naval stores operations and much more is burned to improve the open range, cattle being attracted to the grass on burned areas. Stockmen who have little or no land of their own and depend for their livelihood on the open range are naturally woods burners, and local public sentiment has generally supported them.

Damage from woods burning is relatively slight, as a rule, in the longleaf pine type compared with other forest types. Indeed, as suggested in an earlier chapter, many commercially valuable second-growth longleaf stands have originated and de-

veloped on land promiscuously burned. Nevertheless, much damage on such areas could have been avoided by careful burning.

Early dire predictions about the failure of longleaf regeneration have been largely realized, but failure was due to overcutting, lack of seed trees, and damage from hogs, rather than fire. Losses due to ordinary fires on protected and unprotected lands have been relatively low because of the intrinsic resistance of the species. Destruction of first-year longleaf seedlings by fire, however, has undoubtedly prevented many cut-over areas from reproducing.

Fire losses are undoubtedly greater in the naval stores belt than elsewhere since turpentine removes a portion of the protective bark. Reports on 96 naval stores holdings show a total annual loss in the period 1930-34, inclusive, due directly or indirectly to fire, of 3.9 percent of the merchantable or potentially merchantable trees where slash pine predominated, 3.6 percent where slash and longleaf pine were equally represented, and 3.1 percent in predominantly longleaf stands. The average annual loss in working and resting timber killed directly by fire is roughly estimated by operators at only about 0.5 percent of merchantable or potentially merchantable trees.¹

In contrast to the generally slight losses from frequent fires, accumulations of surface fuels in long-protected forests have resulted in some devastating fires. Ten or 20 years ago total fire exclusion was attempted by some owners of longleaf lands, and efforts were concentrated on the development of effective techniques of prevention, preparedness, and suppression. Notable advances were made in organization, equipment, and fire-control techniques. In this way, large areas were protected for long periods, and timber losses were progressively reduced, but costs per acre remained at about the same level. Despite this progress, some severe fires occurred in the turpentine forest in stands of considerable size, the damage approaching 100 percent in some spots. In dry periods catastrophic fires occasionally destroyed many years of timber growth in a few hours (159, 161, 164, 202, 611).

When the hypothesis of the need of fire in growing longleaf pine forests was first announced, many conservationists regarded it only as a dangerous theory. Many lumbermen and timber owners, on the contrary, interpreted it as a vindication of their common sense and experience. While those advocating the need for fire did not intend to discourage general fire protection, the possibility of widespread misconception indicated a need for further investigation and competent interpretation of the use of fire for constructive purposes. As will be shown later, longleaf can be grown so economically with fire that it seems inadvisable in most cases to attempt to produce it without the aid of fire.

A few pioneers in timber growing succeeded in gaining the interest of local graziers and thus obtained a measure of control over woods burning. One of these men, Henry Hardtner (235), recommended that cattle grazing and timber growing be combined, but the full possibilities of this dual use of the land have seldom been realized, owing to lack of information on efficient techniques.

¹Liefeld, T. A. Fire damage in Florida and Georgia turpentine operations. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.] The properties on which these estimates are based were under various types of fire protection, varying from complete fire exclusion to frequent light burning, but were most representative of frequently burned lands.

Observations of the very successful large-scale reforestation of longleaf pine areas near Bogalusa, La., have brought out the following facts which, properly interpreted, are helpful in avoiding overemphasis on the need for fire for reproduction purposes other than site preparation. At Bogalusa, protection was not a factor in early establishment of the stands because annual burning continued up to the year of seed fall. Complete protection was started after seed fall and may have delayed, but did not prevent, satisfactory height growth of enough seedlings per acre to make a stand. A few accidental fires occurred and many seedlings grew on burned-over fire lines, but after the first growing season, fire nowhere interfered seriously with the development of young stands. This uniformity of natural reproduction was due primarily to heavy seeding; overcrowding retarded growth more than any fire treatment (Fig. 20, B). Brown-spot disease, induced by overstocking, impeded the development of seedlings more than fire did because it deprived them of more foliage, although such overdense seeding and severely diseased stands are quite exceptional for longleaf pine. The sterilizing effect of fires subsequent to establishment failed in this instance to stimulate height growth of seedlings.

The purpose of protection is to avoid or materially reduce fire damage. A permissible annual burning on 3 percent of the forest area by unwanted fires has been suggested (330) but is not yet a settled policy. In protecting a forest of fire-resistant species, such as longleaf pine, there is some danger that costs will exceed benefits. The formula suggested by Headley (524), called the "least $P + S + D$ objective," may be useful in ascertaining desirable expenditure. According to this formula, damage is regarded as a cost, and the aim is to keep the combined cost of presuppression (P), suppression (S), and damage (D) at a minimum. Increased investment in (P) and (S) is followed by decrease in (D) up to a certain point; beyond that, protection becomes exorbitant. The principle involved in this formula is sound but its utility is limited by difficulty in appraising damage.

Frequent and unrestrained burning usually causes relatively little damage to longleaf pine stands, but after an area has been successfully protected for a few years there is risk of serious damage from an occasional bad fire. Intelligent protective burning lowers this risk without unduly increasing the periodic fire damage. Occasionally, justifiable burning to enhance the forage value of native range grasses or to adjust the available food, cover, range, and nesting habits of game birds, lightens the protective job.

The management of longleaf pine lands requires occasional burning in order (1) to expose a mineral surface as a natural seedbed, (2) to retard brown-spot needle disease, (3) to restrict the encroachment of hardwood or other pines, and (4) to insure against serious loss of growing stock by accidental fires in accumulated litter.

Fire control thus requires a decision not merely as to the amount of money to be spent in over-all protection (including protective burning), but also the role of localized burning for other constructive purposes. This decision must be based on a thorough knowledge of fires, the fuels that feed them, their behavior in longleaf pine stands both under and out of control, and the probable losses and benefits of fire under various conditions. If fire exclusion could eliminate damage within practical cost limits, without introducing serious complications in maintaining the species, this

would be the obvious solution to the longleaf pine problem. Prescribed burning is not only essential in maintaining the longleaf type of forest (Chapter IV), but it is also an effective means of reducing fire hazards, thus making the control job easier. As more longleaf forests are brought under management, the value of well-planned and constructive use of fire should increase; at the same time, indiscriminate and destructive burning will be less and less tolerated.

BEHAVIOR OF FOREST FIRES

A year-long fire season exists throughout the longleaf pine forest type because the fuels will usually ignite quickly a few hours after a rain. Lightning fires are relatively uncommon because of heavy rains accompanying lightning storms, but punky wood may ignite and smolder until the surrounding fuel dries out sufficiently to ignite. In general, ignition is most likely to originate from a flame, since glowing brands, embers, or sparks do not usually start fires in the piney woods.

Winds carry fires rapidly through the flash fuels of the longleaf forest. In dry, fine-textured, standing grass, fire often travels at the rate of 175 yards per minute in the direction of the wind. The rate of spread increases with wind velocity and density of grass, and decreases with compactness and rise in moisture content of the fuel. Compactness of the rough usually increases with age.² The heaviest stands of grass are not dense enough to interfere with combustion, while the less dense stands are sparse enough to check the fire.

The speed of surface fires may be extremely great in the longleaf type. During the Honey fire of January 1938 on an open, cut-over longleaf area in the Kisatchie National Forest, La. (412), atmospheric humidity dropped 7 percent (from 33 to 26) and fuel moisture 4 percent (from 16 to 12), while the wind, at 7 to 17 miles per hour, spread the fire at a rate of 1 to 8 chains (66 feet to 1/10 mile) per minute. Burning in a rough 3 or more years old, the flames at the head reached out in long tongues extending 100 feet. On the flanks, a slight shift in wind direction increased the height of flames from an average of 3 or 4 feet to 20 or 25 feet. About 1,000 acres were burned over.

In the longleaf type "spotting" of fires is frequent where there are dead oak leaves or well-cured pine needles on branches, and usually occurs only in advance of

²The size of a fire in the longleaf type is essentially a function of time, wind, and moisture, and may be expressed as follows: Perimeter in chains = $0.26 (\text{time})^b$ where b equals $1.10 + 0.12 (\text{wind}) - 0.01 (\text{moisture})$, and burning time is expressed in minutes, wind in miles per hour, and moisture in percentage of dry weight. This formula indicates that a change of 1 mile in wind velocity is equivalent to a 12-percent change in moisture content in its effect on the spread of fire. In the longleaf type, the combustible materials need not be as dry as in other types of forest in order to burn readily; with more than 65 percent moisture and the absence of wind, the fuels of the longleaf type will not support combustion. Olson, C. F., Osborne, J. G., and Bickford, C. A. Report on a study of rate of spread of forest fires in the longleaf-slash pine type. 1939. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

As a result of systematic studies of fire behavior, a longleaf-slash pine fire-danger meter was devised by Bickford and Bruce (34). This meter is a slide rule based on wind velocity at 7½ feet above ground, the moisture content of basswood indicators, and the condition of the herbaceous vegetation. Another meter developed by Jemison (320) and used in some parts of the longleaf belt recognizes days since rain as an added factor. The various conditions affecting the spread of fires indicate the need for only one fire-danger station per ranger district in the longleaf pine region; in other regions, several stations in each district are needed (325).

the head. Burning leaves in the rising column of hot air are swept upward until caught by the prevailing wind. During the Honey fire, hardwood leaves, especially from blackjack oaks, were responsible for all the spot fires noted. In one place, with a wind of 13 miles per hour, the fire spotted over 200 feet in advance of its head, which was finally intercepted by a camp site covered with closely grazed carpetgrass.

Although fires ignite easily and spread rapidly in southern pine, they are controlled more easily than in other forest types. The output of fire line constructed and held in the South from 1936 to 1938 averaged 1.93 chains³ per man-hour compared with 0.43 for the Nation as a whole. Properly trained and led fire fighters should be able to produce and hold 6 chains per man-hour in longleaf forests (271).

EFFECTS OF FIRE IN ESTABLISHED STANDS

Although longleaf is unquestionably the most fire resistant of the southern pines, and timely burning helps new stands to become established and dominant on certain sites, severe burning may kill or injure many trees.

Four major factors influence the effects of fire: (1) weather, before, during, and after the fire, (2) season of the year, in relation to active growth or dormancy, (3) combustibility of materials, i.e., the character, quantity, and distribution of litter, herbaceous fuel, and undergrowth, and (4) character of the stand. Secondary factors include topographic and soil conditions, recurrence of burning, and the subsequent incidence of insect attacks and disease.

Growth Retardation from Fire

A single fire causing heavy defoliation among sapling and pole-sized trees commonly results in a loss equivalent to about 1 year's normal height growth—the loss being distributed over about 3 years, with 60 percent in the first, 30 percent in the second, and 10 percent in the third year following the fire. Among trees of this size, the smaller individuals usually lose most foliage, and growth is retarded in proportion to defoliation. Repeated defoliation following later burns continues to retard growth. For example, in South Carolina a retardation of 27 to 42 percent was noted in the yearly height growth of longleaf saplings 4 to 12 feet tall at the start of 4 years of annual burning (383). Again, some 1,200 longleaf saplings 3 to 6 inches in diameter were sampled in national forest areas in Mississippi and Louisiana in order to observe the effect of recent fires on diameter growth. Actual growth following burning was compared in each instance with growth of the same trees before the fire. Retardation ranged from 0 to 65 percent, depending on degree of defoliation. Larger trees, with higher crowns, were less severely scorched and their diameter growth was impeded about 19 percent on the average—never more than 35 percent. Although some fires had no perceptible effects, the average first-year loss of diameter growth following 27 single burns approximated 23 percent. Normal growth was resumed in 2 or 3 years (539). In South Carolina, 13 annual fires reduced the mean volume growth of longleaf saplings 1.3 to 9.3 feet high 22 percent (369). In another

³The output has not been determined for the longleaf pine forest separately, but it is known to be still higher.

test, the reduction of mean basal-area growth inside bark was 36 to 75 percent as a result of only 3 annual fires (372).

Diameter growth of small trees is appreciably greater on unburned than on severely burned land. Since not all unprotected land is burned over severely, or completely, fire protection can perhaps be credited with increasing the diameter growth of small trees not more than one-third (21). This estimate applies to longleaf pine only in the regeneration stage and, in the absence of thinning, is subject to later reversal. In the Roberts plots,⁴ this change came between the eighteenth and nineteenth years after seed germination, and on the larger trees was manifest between the sixteenth and seventeenth years (Fig. 43, B). Thereafter, in spite of continued burning, the average diameter growth on the burned plot exceeded that on the unburned sample plot by about 40 percent. This reversal of trend was due to the temporary availability of more growing space, resulting from the stunting of the smaller trees by earlier fires. The early superior growth of trees on the unburned check plot could have been maintained by thinning the stand.

Retardation of height growth by fire diminishes with age and increased size of trees. Fire seems to have no retarding effects if crowns are not defoliated. If it be assumed that normal development in longleaf is 4 feet of height growth in the first 8 years, followed by annual increments of 3 feet, annual hard winter fires reduce the rate by about 30 percent. Freedom from fire permits a resumption of the normal rate in 2 or 3 years. By contrast, severe summer fires reduce growth 50 percent, and complete recovery under subsequent protection may take more than 3 years (399).

Scorching and heat killing of foliage is often most damaging in the late seedling stage. At 10 years of age, longleaf seedlings on one annually burned plot were less than half as tall, on the average, as those on an adjacent unburned plot (147). Severe retardation of height growth as a result of defoliation is common when the trees are between 1 and 5 feet tall. (As much as 10 inches of height growth was lost in a single year in one instance from an accidental March fire.) When the trees exceed 5 feet in height, complete defoliation and reduction in height growth is less common, even under annual burning. Trees with crowns well above the low flames of grass fires, that is, those over 1.6 inches d.b.h. and 10 feet in height, usually suffer very little from fire.

Large saplings and pole-sized trees are retarded by severe fires. MacKinney found that in South Carolina 13 annual fires reduced the yearly height growth of trees between 5 and 40 feet tall about 0.5 foot (370). Annual uncontrolled winter burning in a southern Mississippi forest retarded the height growth of trees 27 to 40 feet tall about 25 percent in a 5-year period, and 20 to 25 percent in a Florida stand (83, 587).

⁴Remnants of the original longleaf timber logged in 1904 reseeded the area from a heavy seed crop in 1913. Starting in 1915, experimental burning and observation has continued to date. In 5 years, hogs reduced seedlings outside the fences to 8 per acre and because of this thorough destruction, burning on outside plots was discontinued, permitting reseedling to loblolly. Between the sixteenth and seventeenth seasons, when the contrast in growth rates of the larger trees reversed itself, an examination of the annually burned-over soil in the longleaf pine stands indicated a higher hygroscopic water, nitrogen, and carbon content, and a higher replaceable lime and magnesia content in the two top layers, and a lower replaceable potash content in the actual mineral soil. To a depth of 8 inches, the burned plot was less acid than the unburned, while in the 8- to 12-inch layer the pH value was the same.

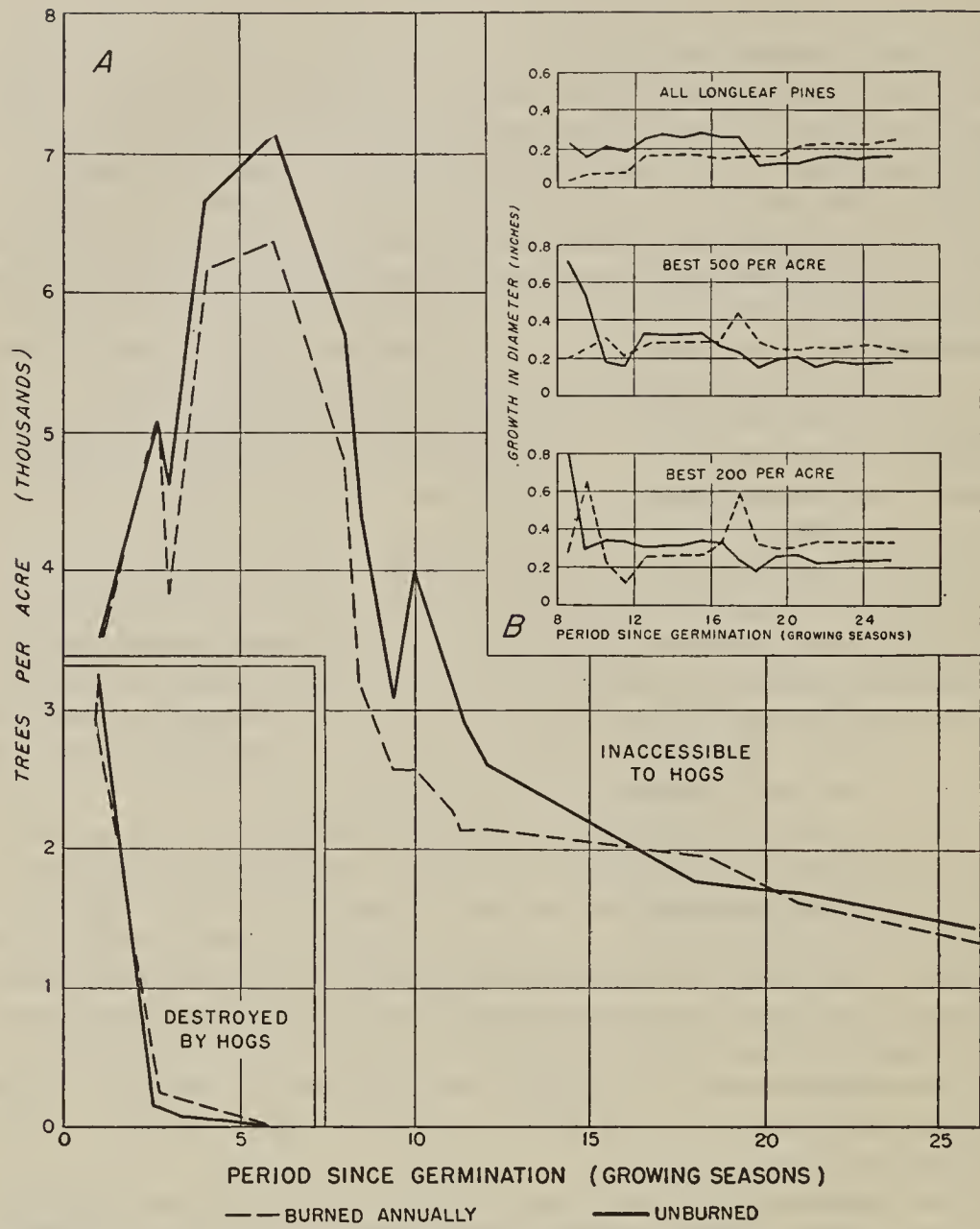


Figure 43.—Effects of annual fires and hog grazing on density and diameter growth of longleaf pine in young stands (Roberts plots, Urania, La.). Note that in *A* all seedlings were killed by hogs within 6 growing seasons, while stands inaccessible to hogs had in later stages a normal survival rate regardless of burning treatment; *B* indicates that annual diameter growth was greater in the unburned than in the burned stand until about the eighteenth year, but thereafter the burned trees maintained superior rates of growth. (After Bruce)

In the above examples, the contrast between burned and unburned treatment was observed over a 10- to 15-year period of height growth. In a longleaf seedling stand subjected to indiscriminate winter burning, normal height development seems to start later, suffer temporary retardation, and then resume the rate characteristic of un-

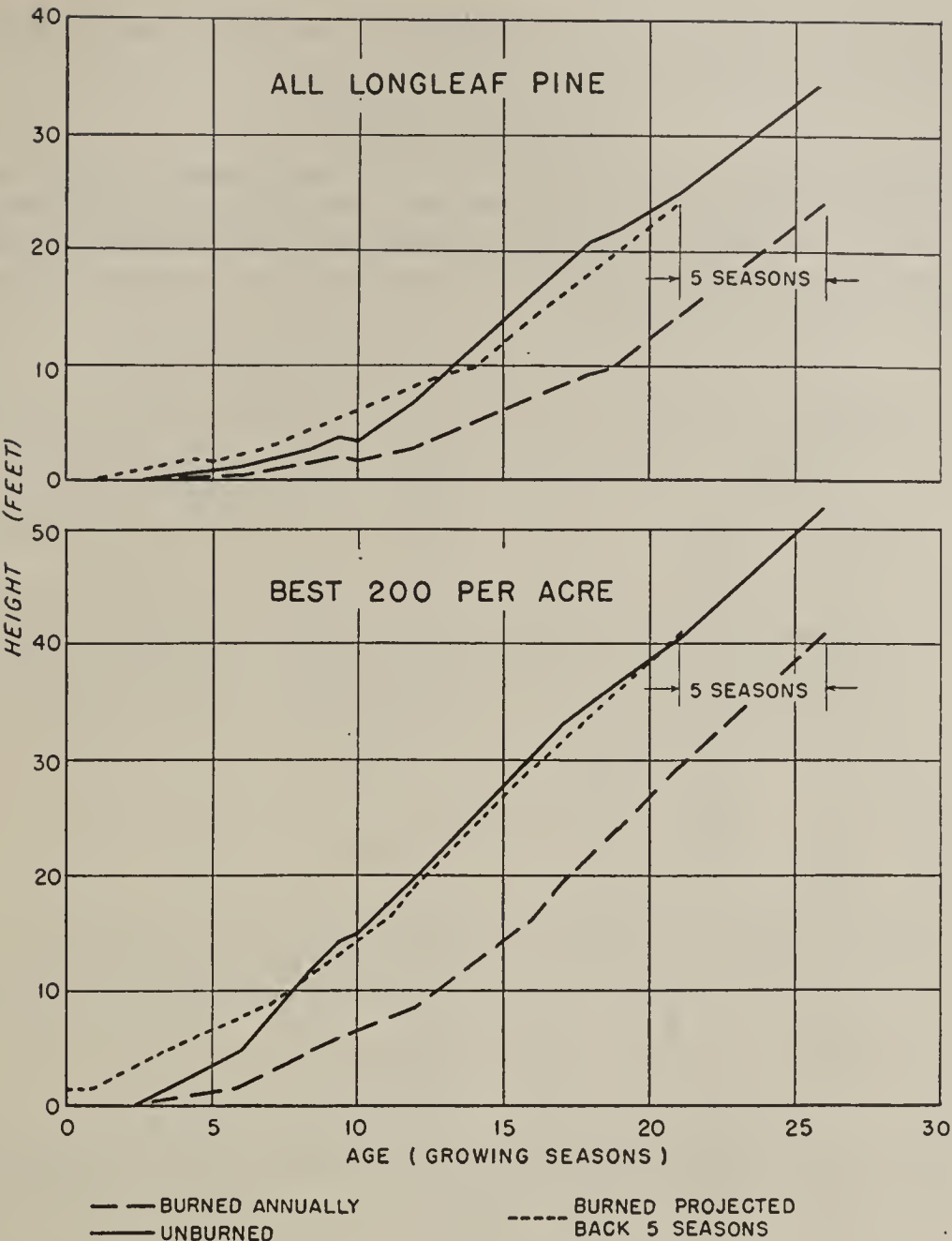


Figure 44.—Effects of burning on height growth of longleaf pine (Roberts plots). (After Bruce)

scorched trees. The Roberts plots behaved in this manner. Here the annually burned saplings, particularly the potential crop trees, now closely resemble in average height and rate of annual height growth those of the unburned check plot of 5 years ago. In other words, the loss from annual burning in this instance was equivalent to about 5 years of height growth (Fig. 44).

At 26 years of age the cubic volume of wood on the annually burned Roberts plot was about half that on the unburned plot, and equal to that on the unburned

plot 6 years earlier. After 25 years of age, this difference may be expected to diminish or disappear in a longleaf stand if no thinnings are made.

Mortality from Fire

Mortality from fire may likewise be heavy in the early stages of a longleaf stand. At all stages of development the trees are more often scorched than killed and may be completely defoliated without dying. Consequently mortality following a fire often cannot be promptly appraised. The effect of typical uncontrolled fires on mortality is shown in Figure 45.

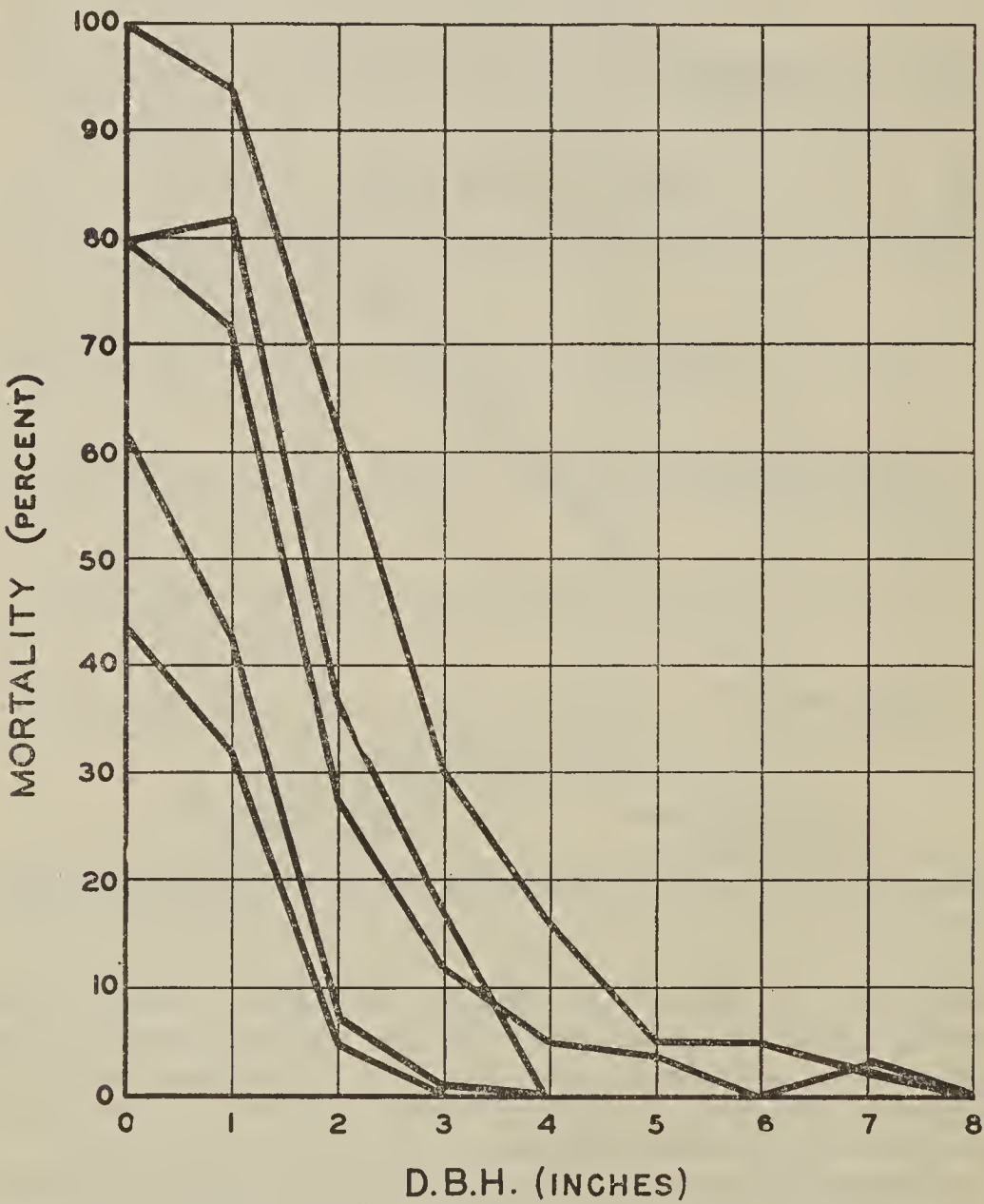


Figure 45.—Mortality in relation to diameter of longleaf pines, in 5 separate fires, southern Alabama.

Because trees that ultimately die from the combined effects of fire and insect damage frequently send out new leaves after complete defoliation, accurate mortality records cannot be obtained until the close of the growing season following a fire. Some conception of probable mortality may be noted sooner from studies of defoliation and subsequent death of trees in similar stands. To this end, apparent crown injuries were classified by MacKinney (371) 11 months after a severe accidental fire among 30-year-old longleaf pines, standing 280 per acre on a site unburned for the previous 12 years. The fire consumed 7,000 pounds of dry litter per acre and scorched bark to a height of 7 feet. The results demonstrate the extent to which longleaf pine can endure even severe fires. Mortality was as follows: the 1- to 29-percent defoliation class lost 6 percent of the trees; the 30- to 54-percent class lost 25 percent; the 50- to 79-percent class, 47 percent; the 80- to 99-percent class, 50 percent; and trees 100 percent defoliated, 73 percent. The fire was hotter than usual, and the saplings suffered severely. Similar losses distributed among diameter classes are indicated in Table 40.

Table 40.—Mortality of second-growth longleaf pines from severe fire during drought, by diameter classes¹ (After Demmon)

Diameter breast high (inches)	Original trees per acre	Trees per acre killed by fire	
	Number	Number	Percent
1	16	16	100
2	200	200	100
3	224	160	71
4	304	164	54
5	196	60	31
6	72	16	22
7	24	0	0
8	8	0	0
Total	1,044	616	59

¹Location: northeastern Florida. Another study in the same locality showed that mortality of 3-inch trees was about 22 percent in mid-day fires, but only 4 to 7 percent in late afternoon fires.

Over a restricted range of sapling sizes above 3 or 4 inches, any single fire may show a rather close and apparently linear inverse relationship between diameter and mortality. In one instance, mortality dropped 16 percent per inch of diameter for saplings between 1 and 7 inches d.b.h. This simple relationship, however, cannot be used for prediction purposes. This is apparent from Figure 46, where mortality trends are compared for fires killing from 5 to 95 percent of the trees in young stands. Here, over a wide range of sizes of both seedlings and small poles, the relationship is curvilinear. Mortality due to the common light fires, killing less than 15 percent of the stand, was confined to trees below the 3-inch diameter class. Trees above about 8 inches d.b.h. suffered no mortality until the fire was sufficiently intense to wipe out over 40 percent of the stand.

Figure 46 might be interpreted to mean that in fires producing over 30 percent mortality, seedlings in general are more fire resistant than 1-inch saplings. It is true that seedlings in the grass, if dominant, are less likely to be killed than are small saplings, but those between 1 and 4½ feet high are more vulnerable than saplings. Because of these responses, burning to disinfect or protect seedling stands is usually desirable before height growth starts. Thereafter, the seedlings should be protected

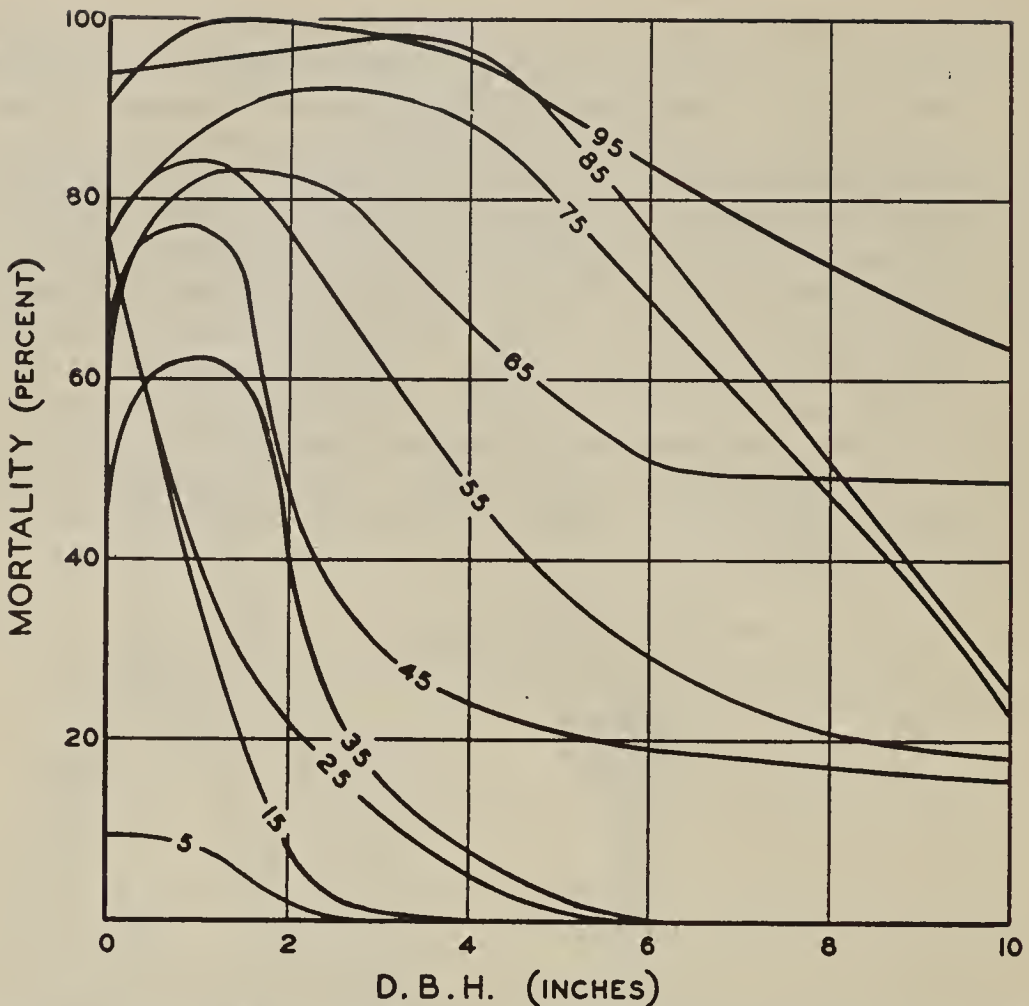


Figure 46.—Relationship between diameter and mortality from fires of different severity in 25-year-old longleaf pine, northern Florida. The figure on each curve shows severity in terms of the percentage of trees killed.

until they develop into saplings. Another possible exception to the general rule that fire resistance increases with the size of longleaf pine is that greater mortality from burning may occur in 9- to 13-inch trees with turpentine faces than in 4- to 8-inch round trees (146). This is true only of fires that ignite the faces.

Unless fire travels in the crowns of trees, its speed is retarded when it enters dense timber, apparently because the surface fuel is more compact, the atmospheric humidity is higher and the wind velocity is lower than in open-grown timber. Severe fires sometimes completely heat-kill many crowns, but usually the flames consume only portions of the crowns of larger trees. The extent of crown burning and resultant mortality of trees depend, among other things, on the density of stand. Thus it was found that in one instance where stands had the same average diameters, mortality of trees appeared to rise at the rate of about 3.5 percent with each increase of 100 trees per acre. Noncommercial thinning of closed stands of young pines greatly reduces the probability of heavy damage from crown fires (Pl. 29). In March 1931,

for example, seven 1/10-acre thinning plots were established in a 19-year-old Georgia longleaf pine stand with a 6- to 7-year rough. The series contained a pair of originally comparable plots, both thinned to 300 trees per acre. One was burned under control and the other remained unburned. In April 1932, a severe accidental fire killed 80 to 100 percent of the trees on the unburned plots. By contrast, on the plot burned the year before, mortality, including subsequent *Ips* beetle damage, was only 7 percent (Pl. 29).

Wind velocity and direction greatly affect the behavior and damage of fires. Where the head of one daytime fire killed 51 to 59 percent of the trees, the same fire burning at night against the wind killed only 3 to 27 percent of the trees. Longleaf pine seedlings not seriously weakened by competition or disease usually suffer less damage from backfires at night than these figures indicate. The higher moisture content of forest fuels, as well as greater atmospheric humidity and lessened wind velocity, help to explain the smaller night losses. Table 41 contrasts mortality from fire under different atmospheric conditions in a pure even-aged stand of second growth.

Table 41.—*Mortality in pure, even-aged longleaf pine, second growth, from fire under different atmospheric conditions*¹ (After Demmon)

Diameter breast high (inches)	Dry conditions ²		Moist conditions ²	
	Trees per acre	Trees killed by fire	Trees per acre	Trees killed by fire
	Number	Percent	Number	Percent
1	304	97	156	3
2	248	74	208	0
3	56	29	188	0
4	104	38	76	0
5	104	15	48	0
6	56	14	28	0
7	32	25	16	0
8	24	0	8	0

¹The fires followed 7 years of protection from both burning and grazing.

²Under dry conditions in October the fire burned rapidly in an air temperature of 69° F. and relative humidity of 41 percent. Under moist conditions in January the fire burned slowly with an air temperature of 55° F. and relative humidity of 100 percent. All pines less than 1 inch d.b.h. were badly stunted. The light fire killed 75 percent and the heavy fire all of the lingering seedlings.

Table 42 shows mortality distribution by crown classes following the severe burning of second growth marked for thinning but actually thinned only in part. In the unthinned stand, the subdominant trees succumbed in large numbers, their death rates increasing with degree of suppression. In the thinned stand, there were none of the subdominants most susceptible to fire, and less mortality was found among dominants.

All the evidence available points to the conclusion that indiscriminate burning may occasionally have beneficial effects in some longleaf pine stands, since it is immaterial whether the weaker trees die early from fire or later from other causes. Unless the stand is badly overstocked, however, hard burning should be avoided. Pruning benefits may accrue, but on the whole, fire cannot be recommended unreservedly as a means of either thinning or pruning a stand until it can be more precisely controlled than has been possible so far.

In addition to retarded growth and increased mortality, some damage results from fire scars that expose valuable butt logs to decay. Nearly all cases of butt rot

Table 42.—Mortality, by crown classes, following a severe April fire in a partly thinned, second-growth longleaf pine stand, Osceola National Forest, Fla. (After Demmon)

Portion of Stand	Crown class			Total
	Dominant and codominant	Intermediate	Suppressed	
	Trees killed by fire			
All trees:				
Number	60	204	352	616
Percent	20	57	90	59
Trees marked for removal:				
Number	48	204	352	604
Percent	24	57	90	64
Trees chosen to remain:				
Number	12	---	---	12
Percent	12	---	---	12

in longleaf pine can be traced to scars formed during the early life of the trees (420). Such scars, however, are rarely initiated by fire alone except possibly in trees close to slow-burning lightwood knots. Logging bruises, burned turpentine faces, and turpentine beetles (298) are responsible for most early scars. Once a scar is made, each creeping fire serves to enlarge it.

In a survey of virgin timber reported by Demmon (145), a comparison was made of visible fire scarring in different species of southern pine. For all sizes, the average was 11.5 percent of the trees scarred in shortleaf pine, 25 percent in longleaf. Among the small-diameter classes, longleaf was still more severely scarred. This was not due to inferior fire resistance of longleaf, since even in the most susceptible sizes the species is more resistant to fire than any other native pine. The reason is that the generally higher mortality of other pines left fewer scarred trees alive after former fires; in other words, fire-scarred trees usually survive longer if they are longleaf pines.

Recurring fires in virgin timber enlarged butt injuries. On basal wounds caused by abrasion, boxing, heavy chipping, or the larvae of turpentine beetles, resin ignited by surface fires often burned for a long time. The subsequent checking of exposed wood provided avenues of entrance for insects and decay organisms. Slow attrition from these causes has destroyed or degraded the wood in otherwise valuable butt logs, and often so weakened the old-growth trees as to make them easily subject to windthrow.

Heavily turpented and abandoned second-growth trees are also degraded or destroyed by recurrent fires. Round and conservatively worked trees are the least affected. Under management that includes the salvage cutting of injured and worked-out trees, second-growth stands can be maintained in good condition despite frequent woods burning.

FOREST FUELS

The typical fuel in the longleaf type is grass with an admixture of hardwood leaves, pine needles, and minor debris, and a variety of shrubs such as waxmyrtle (*Myrica cerifera*), gallberry (*Ilex glabra*), palmetto (*Serenoa repens*) and flowering dogwood (*Cornus florida*). In some localities there may also be an understory of hardwoods, such as oaks, gums, and hickories. Rapid wetting and drying—mainly

because of the abundance of finely divided and more or less erect grass—is characteristic of longleaf fuels.

The amount of fuel or “rough” depends on the period since burning and also on the site, density, age, and composition of the forest stand. Developing stands suppress and kill many kinds of underbrush, but they reduce gallberry and palmetto slowly if at all. Decomposition gradually overtakes and offsets the accumulation of dead material. This process may continue up to 20 years in pine stands, but in the grass rough of open areas it leads to an equilibrium in about 3 years. On the other hand, the litter of fully stocked stands accumulates rapidly during the first 3 years after burning, moderately up to the tenth year, and remains nearly stationary thereafter.

Measurements have been made of the litter in a 25-year-old longleaf pine forest growing on Orangeburg fine sandy loam free from underbrush. In a 1-year straw rough, there was an average depth of $2/3$ inch and dry weight of 3,433 pounds per acre. On a similar area, unburned for 5 years, the average depth was 1.9 inches and the dry weight 15,167 pounds per acre.

The underbrush hazard in unburned woods seemingly continues to build up indefinitely in open stands, and on moist sites in some denser stands as well. Where needles, hardwood leaves, and other debris lodge on lower limbs, underbrush, and vines as well as on the grass below, a very bad fire hazard results. Long, dry needles festooned over other inflammable materials constitute a fuel that burns with explosive violence. To determine the amount of fuel that may develop, a sample of material that would burn in an ordinary head fire was gathered from a 15-year rough under a dense stand of longleaf poles on the Osceola National Forest. When air dried and weighed, this sample indicated the presence of about 25 tons of fuel per acre. On some long-unburned areas, the dense underbrush laden with litter may easily carry flames into the crowns of young trees.

Scrubby undergrowth has often become sufficiently dense and continuous in understocked stands to promote destructive crown fires in pines, especially during extreme drought. Scrub oaks like blackjack increase the available fuels appreciably because their leaves hang onto the branches long after becoming brown and inflammable. Dry leaves on the lower branches, exposed to the lesser wind velocities near the ground, may promote crown fires among the oaks. The oaks are entirely bare only for a short time before the new leaves come out. Palmetto and gallberry are persistent even in the better-stocked portions of second-growth longleaf forests. Except on the moister sites, however, fully stocked stands of longleaf usually have no menacing undergrowth, and the fire danger is reduced because root competition and straw fall interfere with the growth of minor vegetation. Accumulations of needle litter are less well aerated than grass and hence burn more slowly, and the trees themselves hinder the movement of air.

Tops and logging slash left in timber cutting temporarily create special fire hazards, although slash constitutes much less of a hazard in longleaf forests than in most coniferous types. Some dead needles cling to treetops for two years, and appreciably increase the hazard.

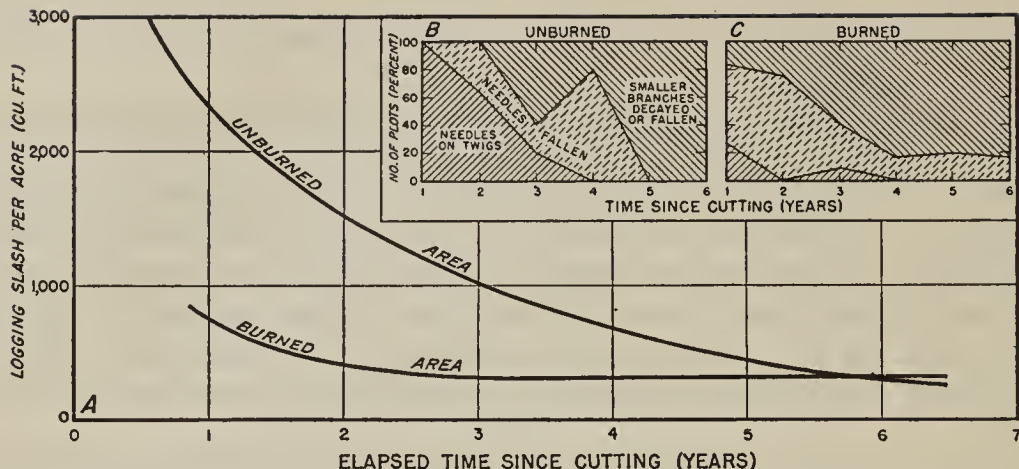


Figure 47.—Rate of disintegration of logging slash in pulpwood cutting in the longleaf pine type. *A*, volume of slash on burned and unburned areas; *B*, volume of needles on twigs, fallen needles, and smaller branches decayed or fallen on unburned plots; *C*, similar material on burned plots. (After Gemmer)

The disintegration of logging slash in pulpwood cutting is portrayed in Figure 47, which indicates the relative scarcity of fuel on burned areas. The hazards and fire-control difficulties added by pulpwood cuttings reach a peak in about 3 months and then gradually diminish, disappearing after about 30 months. Twigs, bark, and sapwood are not highly inflammable.

FIRE CONTROL

Fire prevention relies mainly on the good will and cooperation of local people. In the longleaf pine belt, those who conduct fire-prevention campaigns must recognize the benefits of fire in managing longleaf pine. Failure to admit these advantages has defeated much prevention effort. Local public sentiment has not been in harmony with public policies and under these conditions law enforcement is ineffective. An increased public appreciation of forest values and the role of controlled fire in silviculture and protection will tend to rectify this condition.

Fire-control equipment and facilities in the longleaf region resemble those found elsewhere. They include lookout towers; telephones and radios; machinery for constructing fire lines, firebreaks, and fire lanes for backfiring; and vehicles for transportation of crews. In the longleaf belt, some towers are more than 24 miles apart, but 12 miles is a better spacing if triangulation is to be used in locating columns of smoke.

Communication and Transportation of Fire Fighters

The short-wave radio for dispatching fire fighters is a useful supplement to the telephone. It shortens elapsed time between discovery and attack and therefore reduces the area burned. Fire crews can start before the triangulation of a smoke column has been completed, being informed en route of the location. Improved communication reduces the need for excursions to and from headquarters, thus saving

wear and tear on trucks and tires. Two-way radio communication systems are preferred in protection work, but a one-way system is sufficient where a forest is readily accessible to cars and trucks and has been provided with telephones. On one forest in southern Georgia, annual fire losses were reduced from an average of 5 percent to a small fraction of 1 percent of the area protected following the introduction of short-wave communication (411).

A good road system is necessary in forest-fire protection. Firebreaks in the longleaf type seldom stop a head fire and sometimes even fail to stop a flank fire. Their principal value is to furnish a backfiring chance and to provide a low-grade road which can be traveled at least 10 to 15 miles per hour in delivery of men and equipment. The burned-over fire lane is less necessary when a system of motorways or low-grade roads has been extended throughout a forest. A strip between a woods road and parallel furrow may be burned over to provide a barrier, since the road itself will stop only the creeping type of flame. The main protective value of such roads is in making the whole forest quickly accessible to fire-fighting crews.

Fire-Control Equipment

Special machinery for fire control, particularly various kinds of power-operated plows for making furrows, is constantly being developed and improved (Pl. 30). Among the models available are plows with 2 to 5 disks whose cutting depth is regulated by the adjustment of the wheels used for transportation between jobs. The plow cuts are from 3 to 7 feet wide and the soil cast beyond the shoulders on either side extends the range to 11 feet. It can be pulled by a crawler-type tractor. One or two men may be needed to remove obstacles from the path of new lines (357). Ingenious creations for controlling grass fires range from the single-purpose, 55-pound "middle buster" pulled by a crew of men, to the double-purpose, power-drawn Mathis plow that utilizes a rolling coulter, double mold-board, disks, flanges, and flame throwers for automatic backfiring (400, 511).

The most efficient fire-fighting crew is small, mobile, and equipped for instant action. Specifically, this means 4 or 5 trained men in a light motor truck equipped with a tank of water, power pump, backpack pumps, flaps, rakes, etc. The truck is driven into the woods along the margin of the fire, one man using the hose and the others following to secure the line. When everything "clicks," the output of such a crew will often exceed 6 chains per man-hour.

When the ground is wet, trucks may become helplessly mired after leaving a well-traveled road. Dual wheels are therefore preferable. For rough-and-ready woods travel, encouraging results have been obtained in Mississippi by mounting the tanks and power-driven pumps on a tractor base. Further experiments, however, are needed to determine the specifications for the most useful mechanized units. For example, there is need for a small high-speed tractor-plow outfit that can reach the woods as quickly as a truck, and that can pass over logs, run through brushy swamps, and extricate itself when stalled in a bog. Army jeeps may be useful in fire fighting.

Most fires fought in the longleaf forest are kept within small areas, but now and then one gets out of control and burns 1,000 acres or more. The essential thing in subduing a fire is to stop the progress of its head. Backfiring from roads in advance

of a running fire is good practice, but a common mistake is to backfire too close to the head.

Protective Burning

Occasionally, unusual fires reach into the crowns of trees and cause heavy damage in established longleaf stands. This is particularly true when fire protection and control fail during severe drought. These catastrophies have occurred often enough in rough woods to be a constant concern. Since stands of longleaf that have no heavy rough are damaged but little by light winter fires occurring about once every three years, the desirability of protective burning under these conditions is obvious. The need of wide barriers to stop head fires, together with the increasing realization of the silvicultural advantages of fire for other purposes in growing longleaf, has led to an expanded use of protective burning.

A burn facilitates protection by removing fuel accumulations, thus temporarily eliminating the possibility of wild fires or lowering their possible intensity. Protective burning must be frequent enough to remove dangerous fuel accumulations, yet not so frequent that lack of fuel would prevent a clean burn under slow-burning conditions. Protective burning also should avoid excessive killing of recently germinated seedlings. It can often be readily combined with burning prescribed for silvicultural and other constructive purposes such as range improvement for game birds or livestock.

In 1935, H. L. Stoddard (533), describing his experience with fire adapted to game management, said: "Such burning as proves desirable should preferably be carried on during the dampness of the night and against the wind if there is any blowing. If the fire lanes are numerous and in good condition, and the units small, such night burning requires less supervision than does the burning of large tracts by day. Carried on as recommended, three or four years' accumulation of highly combustible wire grass or broom-sedge can be removed without seriously scarring growing timber or killing the thicket it is desired to save." Recent experiments confirm the wisdom of this practice and show that daytime burning is also useful. It should be done in winter, against a steady wind of moderate velocity, and in manageable blocks bounded by fire lines or natural barriers. In a given place the interval may well vary between 3 and 10 years, depending on the rate of accumulation of inflammable materials, but it is essential that some burning be done every winter, that each burn have a valid purpose, and that the areas burned over each year be well distributed.

Protective burning is desirable throughout the longleaf pine belt whenever its use will minimize the sum of the three principal elements of fire costs (presuppression, suppression, and damage). In commercial longleaf forests and where the soil is not subject to erosion, properly located and controlled winter burning is not only cheaper and safer than complete fire exclusion, but it also tends to maintain the longleaf forest in a natural manner (122, 33). (See Chapter IV.)

Controlled burning prescribed for protection or other definite purposes requires careful burning of a specific area according to a fully developed plan by men trained in handling fire. Those who use fire should (1) analyze its value in each forest stand

or compartment, weighing anticipated benefits against costs and probable damage; (2) burn only where and when benefits outweigh the costs and damage; and (3) burn intelligently and take as much advantage as possible of all factors affecting the results—such as seed crop, weather, fire-danger rating, and natural barriers. Bickford and Curry (33, 36) have set down the principles governing the use of fire in the protection of longleaf and slash pine forests.

The difficulties and costs of both fire use and fire control are influenced by the physical features of the land, including the nature and distribution of natural fire barriers. In many parts of the longleaf region there are numerous hardwood "bays" that form natural barriers, dividing properties into small blocks more effectively than can be done by fire lines. Many hardwood bays are effective fire barriers even in drought years. The "ponds" of the flatwoods usually form natural barriers also, but in dry years the forest floor becomes highly inflammable. In the rolling uplands, where farming and turpentine operations are often combined, cultivated lands serve as fire barriers, the timber occurring characteristically in small blocks separated by draws, "branches," or spring heads in depressions, and by tilled fields on the ridges.⁵ In much of the Upper Coastal Plain in Mississippi and Louisiana, the longleaf forest occurs on the higher ground interspersed with strips and patches of hardwood forest that occupy about a fifth of the land area and provide useful fire barriers.

Fire lanes supplement natural barriers in confining fires to limited areas. They vary from relatively clean narrow lanes to wide burned-over strips. The choice and arrangement of burned fire barriers vary with forest condition and the size of the forest property. Protective burning should be designed to create fire barriers that will eliminate the threat of conflagrations.

Wide lanes bounded by plowed lines may be burned annually in winter, or separate strips or blocks may be burned over on a rotation plan. Various burning cycles are applicable. One plan calls for burning over one-third of the forest every year, preferably in scattered locations, so that the rough never exceeds 3 years. If this plan is followed, one-third of the forest will have been burned every spring, one-third will have a 1-year rough, and one-third a 2-year rough. This cycle fits in well with the requirements for game and range management and provides ample areas of thin fuel where direct attacks on wild fires will be most effective.

In some cases it is advisable to limit the annual burn to 15 percent of the forest area, or even to 7 or 8 percent. For protective purposes an annual burn of 10 percent—or a burning cycle of 10 years—would provide barriers 528 feet (0.1 mile) wide a mile apart, or 264 feet (0.05 mile) wide half a mile apart, where strips run in one direction only, or about half these widths in a grid system. In most parts of the longleaf belt, there are sufficient natural firebreaks so that strips running only one way would offer a high degree of protection. If wind direction common to bad fire days can be recognized, barriers should be planned to run at an angle of 60 degrees or less to the wind. Whether the plan calls for burning one-third or one-tenth of a forest annually is relatively unimportant, but it is essential that a part be burned

⁵Liefeld, T. A. Fire damage in Florida and Georgia turpentine operations. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

over every year, and that the work be planned to provide ample firebreaks where light fuels will permit effective suppression under all weather conditions.

Some owners of large timber tracts in the naval stores region are now using fire in stands previously protected for 10 years or more. After surrounding the areas to be burned with a plowed line, they wait for moderately strong north winds following rains. These winds usually hold for 2 or 3 days, thus minimizing the possibility that the wind may shift and the fire get out of control. When wind direction is too variable, the fire may be too hot or not hot enough. A 90-degree or greater change in wind direction is the worst hazard in burning. Gusty fluctuating winds often convert a backfire into a damaging head fire and should be strictly avoided. Steadiness is more important than any particular velocity. Velocities of 5 to 10 miles per hour are preferable to lower velocities. Both calm and very high winds should be avoided. A moderate wind helps to prevent browning of foliage and keeps flames from entering crowns. Moderately high winds are the most constant in velocity as well as direction.

A geometrical arrangement of plowed lines is not essential on large forest holdings and may be undesirable on small tracts. The mileage of artificial lanes is reduced if full advantage is taken of natural firebreaks. Likewise, rotation burning may well be conducted in a patchwork design adapted to stand conditions.⁶ Burning schedules may differ somewhat according to the objectives sought, but the methods of handling fire constructively are essentially similar, regardless of the type of forest.

Costs of Fire Protection

The traditional method of using fire is to burn the woods lightly every year or at frequent intervals with scant provision for control and hence low cost. Such burning costs but a few cents per acre for labor and precludes severe damage for 2 or 3 years. When State and Federal agencies developed organizations to detect and suppress fires, it was hoped that all fires could be excluded at a cost that would make the continuation of raking and burning in turpentine stands unnecessary. Accidental fires in accumulated fuels, however, have been frequent and sometimes disastrous. Attempts to exclude all fires have neither completely met the needs of private timber growers, nor entirely displaced their use of fire for constructive purposes. As a result, many landowners (including those who rake and burn in turpentine orchards) have come to follow a policy which retains the over-all public protection system with fire lines, lookout towers, guards, and organized fire-fighting crews, but combines this with some form of burning for protective and cultural purposes.

The cost per acre of prescribed burning is low if fire is used frequently enough to make control easy. It may also be kept low by taking long risks on confinement

⁶In longleaf forests organized for sustained yield of quail the following procedures have been used: (1) burning in alternate blocks of 5 to 10 acres, (2) spot burning, and (3) burning progressively down hill. In the block method, natural firebreaks are supplemented by artificial fire lines or lanes around the blocks. In the spot-burning method, the area is divided by fire lines into blocks of 50 to 200 acres, especially if inexperienced personnel are to be used. In burning down hill, plowed or harrowed fire lines are virtually unnecessary. This kind of burning is started on the tops of ridges a few hours after rainfall when the litter has dried out enough to burn. Strips are then burned progressively down the slopes over a period of several days. In this procedure slopes susceptible to erosion should be lightly singed or left unburned.

and control. It is, of course, expensive to use fire with complete safety and to burn an area with a heavy accumulation of fuel without excessive loss. Unusually high burning costs are customary in a heavy rough, where there is a wide range of tree sizes (including regeneration), and where there is an intermixture of the less resistant but valuable tree species. Here an apparently extravagant investment in burning may prove to be the most economical means of avoiding severe damage.

Where turpentine is carried on, periodic raking and burning keeps the woods accessible to field hands and vehicles and prevents the accumulation of fire hazards. Raking is usually done in late fall and winter after turpentine faces have been scraped and most of the dead needles have fallen. Grass, straw, chips, and bushes must be raked or hoed for a distance of about 2½ feet from the tree to keep flames from resinous faces.

The usual raking practice costs 90 cents to \$1.25 per 100 faces or about one cent per tree annually (1944 prices). Burning is an added item although many operators figure that it costs them nothing. Including the labor involved in raking and burning, costs are from 20 to 25 cents per acre (1944),⁷ of which 15 to 20 cents is for raking.

The fire lines needed to supplement natural barriers in the control of fire on large tracts are best made with mechanized equipment, though animal and hand labor are sometimes used. Costs of making fire lines depend on the soil, stand, ground cover, and equipment used. Some preliminary clearing of obstructions may be necessary.

On the Osceola National Forest in Florida, plowing costs in 1944 were \$3 per mile using a 2-disc Mathis plow and a "35" tractor. Plowing parallel lines at ⅛- to ¼-mile intervals, but using other barriers when available, brought the cost up to about 4 cents per acre. Single lines can be built around each 160-acre block, and double lines used to isolate each section, at a cost of 4 or 5 cents per acre (Pls. 31 and 32). Small tracts may be more intensively protected by subdividing them into 10- or 40-acre squares, or by plowing less line around small irregular compartments, partly protected by other barriers.

In general, permanent lines that are prepared in advance of the fire season, as precautions against possible fires, are relatively wide and far apart. They segregate large blocks of forest land. The semipermanent lines that protect smaller compartments are closer together and usually narrower. The temporary lines that are hurriedly made in fighting a fire, or in controlling a prescribed fire to minimize damage, are located only as needed and are narrow. Current needs for wider barriers are met by backfiring inside a fire line or by extinguishing spot fires promptly.

Advance construction of fire lines with tractor-drawn plows—not only advisable but often necessary for safety—may be a major part of the cost. Aside from these presuppression costs and other overhead items, such as supervision of men, their transportation, and the task of extinguishing, the actual labor cost of handling fire

⁷Turpentine men returning to this practice after a period of fire exclusion find that their costs have increased. The average number of faces per acre in the naval stores region is 15 to 19. The cost of raking and burning after 10 or more years of fire exclusion is usually 40 to 55 cents per acre, or \$2 to \$3 per 100 faces (wartime prices), about double the normal cost of continued raking and burning on such areas.

is relatively small. For example, a fire made to back into the wind at the rate of about 1 chain per hour will burn 8 to 10 chains overnight. A crew of 2 or 3 men working from a prepared line can set fire safely at approximately 2 miles per hour, from about half an hour before sunset until fuel becomes too damp about two hours after sunset, resulting in a burn of about 400 acres. On a 5-year burning cycle this will protect 2,000 acres with an outlay of 5 to 7 man-hours annually.

The labor required per acre decreases with an increase in the area burned, although above 100 acres the decrease is small. For a given acreage a burn with a long irregular perimeter uses more labor because it requires more line. The labor needed per acre varies more closely with the size of a burn than with forest type and fuel, although kind of fuel and velocity of wind affect rates of spread and probability of damage. Except on very small areas, the labor cost per acre of controlled burning is usually appreciably less than total protection costs, including damage.

Excluding incidental damage, controlled burning costs on the Osceola National Forest in 1944 were about 9 cents per acre. In northern Louisiana in 1942 they were 6.6 cents per acre (110). For the Gulf States as a whole in 1944 they were estimated to be about 6 cents per acre for the area actually burned over. This last estimate includes a number of burning treatments on private land where the precautions taken for full control were less intensive than in the first instance. Heavy accumulations of fuel and unfavorable winds reduced control and increased damage on the Osceola National Forest above what may be considered normal. Cost plus damage on this forest was estimated at 46 cents per acre in 1944.

Costs of fire protection are usually borne by both the owner and the public. Under agreements in effect in Florida in 1944, groups of owners contributed 3 to 5 cents per acre and State and Federal agencies 3 or 4 cents. States must match with their own funds the Federal allotments received under the Clarke-McNary law, but the use of various special (non-matched) funds causes the Federal-State ratio of contribution to vary from year to year. The total fire protection cost on State and private lands in 1944 is estimated in Florida at 10 or 11 cents per acre. The national forests, under more intensive protection, spend about 5 cents more, or a total of 15 or 16 cents.

SUMMARY

Fires in the longleaf pine type have long been more numerous but less devastating than elsewhere in the United States. Indiscriminate woods burning to improve forage on the open range is common in the longleaf pine type. Nevertheless, the high resistance of longleaf pine to fire has enabled some fine second-growth stands to follow early cuttings. While many large areas of cut-over longleaf land have not reproduced to longleaf, most of the failures are due less to fire than to scarcity of seed trees and damage to seedlings by hogs. While longleaf seedlings are vulnerable to fire in their first year, they are highly resistant later, and less than 0.5 percent of the trees of merchantable size in a stand are lost annually because of ordinary fires.

Accumulations of fuel on unburned areas have led to some very destructive fires. Reproduction on areas frequently burned in the past can sometimes develop thriftily

without further fire, but it is now generally considered that it can be most economically grown only with the aid of burning that periodically reduces the risk of damage from accidental fires.

Fires in the longleaf type can start on almost any dry day when it is not raining. The behavior of the fire depends on the character, amount, and moisture content of accumulated fuels and on wind velocity. Fires spread rapidly in grass fuels in the longleaf forest, sometimes 0.1 mile per minute, but are usually controlled more easily than in other forest types.

On good sites, annual fires kill outright few strong seedlings over one year old. On medium or poor sites, one or more years are needed for seedlings to achieve the strong fire resistance characteristic of the intermediate grass stage. Frequent fires kill many diseased or otherwise backward seedlings and occasional weak trees. The survival rate, of course, increases as burning becomes less severe. For all saplings beyond the 1- or 2-inch diameter classes, and for all sound unturpented trees, resistance to mortality from a given fire increases with size and degree of dominance in the crown canopy. At any stage of development, deep wounding or severe crowding increases mortality due to fire. When individual seedlings or trees that show no promise of ever yielding forest products are killed by fire, the loss naturally does not constitute damage to the stand.

Woods fires hasten natural thinning in crowded stands, thus providing more growing space for crop trees. Full advantage of such space cannot be taken so long as defoliation from frequent fires continues, but when the trees have raised most of their crowns above the usual heat-killing flames, their growth tends temporarily to be faster than it would be in a crowded, unburned stand. By the time growth wanes again, owing to root competition or crown closure, the stand should be thinned by cutting rather than by burning.

In general, annual uncontrolled fires retard the diameter and height growth of longleaf seedlings and saplings by approximately 20 percent. Among sapling and pole-sized trees, heavy defoliation in a single fire commonly results in losses equivalent to about 1 year's normal height growth—the loss being distributed over about 3 years, with 60 percent in the first, 30 percent in the second, and 10 percent in the third year following the fire. Any defoliation is detrimental to growth, and some loss of foliage is to be expected from every fire. When less than a third of the foliage is lost, however, growth retardation is so small as to be difficult to measure. Above this point, the loss in growth is roughly in proportion to loss of foliage.

Scars from turpentine and various other butt injuries, enlarged by fire, permit the entrance of insects and decay that partially destroy or degrade the lumber content of butt logs.

The arrangement, amount, and characteristics of accumulated fuels affect fire hazard. The fuels of the pine-forest floor accumulate up to about 3 years in grassy openings, but where there are shrubs and trees the maximum is not reached for 10 to 20 years. Certain shrubs like gallberry and palmetto persist many years even in well-stocked stands. Additional fire hazards from pulpwood cuttings reach a peak in about 3 months, and disappear in about 30 months.

Roads and plowed lines stop some fires, but serve mainly as avenues of approach and bases for the backfiring work of control crews. In confining fires these crews construct new hand-made lines at a rate in excess of 6 chains per man-hour. The use of mechanized equipment to speed fire control is increasing.

Contrast between the heavy damage by accidental fires in stands long unburned and the light damage in frequently burned stands justifies the use of fire for protective purposes. Adequate control of fire was handicapped for many years by failure to recognize any benefits from burning in the longleaf pine type. Protective burning reduces the number and intensity of accidental fires. Each year a portion of the forest should be burned over in rotation according to a prescribed plan. Such burning is best done in winter either at night, or in daytime against steady winds of moderate velocity. On a given area it should be frequent enough to prevent dangerous accumulations of fuels.

The cost of protection includes damages together with the expense of control. Early attempts at complete exclusion of fire were costly in damages sustained in bad fire years. The safe reduction of heavy accumulations of fuel in forests containing regenerating areas or vulnerable species calls for expensive control and precautionary measures. Such stands may need special treatment. Raking around turpentine trees and plowing of special fire lines are accepted costs in the naval stores region. To keep the total expense of protection and of using fire within reasonable bounds, the work should be so planned that the costs plus damages remain at a minimum over a period of years.

Protective burning can often be designed to provide not only easier protection but also other benefits such as seedbed preparation, sanitation, or range improvement. The skillful use of burning for all recognized purposes should reduce the total costs of forest management in the longleaf region.

IX. Protection From Insects, Disease, Animals, and Climatic Injuries

LONGLEAF PINE is attacked by various injurious agents at different stages of its life. Seeds are eaten by birds, rodents, hogs, and insects. Seedlings are heavily damaged by needle disease, and stripped and gnawed by hogs. Saplings and trees suffer little natural injury except in spots subjected to insect attacks, disease, or storm damage. Trees heavily turpented, wounded, or weakened by crowding or drought are susceptible to insect infestation, decay, and windfall.

Fortunately only a few species of insects cause serious trouble to longleaf pine, and their infestations are usually spotty and small. Defoliators are not common. Longleaf pine may be injured by moths and beetles in one stage or another, but its copious flow of gum destroys many of the boring insects. Insect and fungi attacks are frequently associated.

The highly resinous nature of longleaf pine may account in part for its freedom from epidemics of fungus disease, brown spot being confined to seedlings. Longleaf resists rust canker (*Cronartium*) better than do the other southern pines, and heart rots are not prevalent during the first century of the life of a tree. Climatic injuries normally are not serious in longleaf pine stands.

INSECT ENEMIES

Longleaf is relatively immune to insect scourges. Extant records indicate that epidemics devastated extensive stands early in the 19th century, but such damage has not recurred in recent decades¹ (303, 390, 476).

Bud, Shoot, and Root Insects

The extremely resinous buds and sapwood of the turpentine pines seem to make them more resistant than other pines to most insects. Thus even when longleaf is grown outside its range, the Nantucket tipmoth (*Rhyacionia (Evetria) frustrana* Comst.) is not a pest. The pitchmoth (*Dioryctria amatella* Hulst.) does, however, occasionally attack and kill the shoots of longleaf. It is not fatal to the trees, but retards growth. Under repeated attacks by the pitchmoth, seedlings may become gnarled and deformed, as if damaged by sheep (Pl. 33, A). The pales weevil (*Hylobius pales* Herbst.) has been known to attack longleaf pine, especially in the vicinity of freshly cut stumps. The adults feed on the thinner bark of shoots and branches, damaging seedlings most severely.

¹One of these outbreaks, by an unidentified insect, was a few miles south of the Cape Fear River in North Carolina. Another destroyed 90 percent of the pines on a tract of 2,000 acres near Georgetown, S. C. (387).

The European pine-shoot moth (*Rhyacionia buoliana* Schiff.) has been reported at a nursery in Florida (129). The stems of potentially valuable forest trees may be distorted by this insect, the extent of malformation depending upon the severity of recurring attacks.² Elimination of the foci of infection is essential, if the cost of control measures can be justified. Light infestations on seedlings may be suppressed by repeated spraying or removal of the wormy tips, but the heavier infestations can be handled only by destroying the entire infested stand.

Seedlings are sometimes fatally root-pruned in nurseries by white grubs, the larvae of May beetles or June bugs (323). Cutworms often sever seedlings at the ground line during early stages of development. Midsummer attacks, though less common, have been known to wipe out more than a million longleaf seedlings in a few days. Outbreaks occur suddenly. Control with poisoned bran bait is generally effective.

Ants and Other Defoliators

Enemies of longleaf pine foliage are not numerous. The pine Colaspis beetle (*Colaspis pini* Barber), erroneously called the grape Colaspis, occasionally causes widespread defoliation of young pines including longleaf. There was serious damage from this pest in the Gulf Coast States in 1925 and 1926 (129), and periodically thereafter (520). No control measures seem necessary.

Leconte's sawfly (*Neodiprion lecontei* Fitch) sometimes attacks longleaf seedlings or saplings. It has been identified in at least 3 Gulf Coast States. The adults are robust, black, four-winged, and redheaded. They make shoe-shaped pockets in the pine needles for their eggs. The larvae are $\frac{1}{8}$ inch long when young to $\frac{3}{4}$ or $\frac{7}{8}$ inch in length when full grown. Their bodies are greenish or yellowish with rows of black dots along the sides. The needles are eaten by the larvae, thus causing severe defoliation, especially of seedlings, with consequent stunting in the grass stage, contributing to the death of many individuals (391, 392). The sawfly appears periodically. The cost of control by spraying with lead arsenate seems justifiable only in nurseries.

A needle miner (*Recurvaria* spp.) has been reported from the Choctawhatchee and Kisatchie National Forests. It is found on trees of any size, thinning out the crowns. The mining may possibly affect the production of cones by causing nutritional deficiency, but little serious damage is caused. No control is recommended.

Two species of ants are known to attack the foliage of recently germinated longleaf seedlings, biting and carrying off the cotyledons bit by bit. One, *Crematogaster lineolata* Say., is a medium-sized jet-black insect commonly observed to herd aphids on longleaf pine needles. The other, *Tapinoma* spp., is a smaller brownish-black creature. Both can be very destructive to sprouting seeds and young seedlings (197).

The Texas leaf-cutting or "town" ant (*Atta texana* Buckley) may completely destroy very young seedlings within 300 or 400 feet of its colonies (507, 519). Older seedlings and saplings sometimes also suffer pronounced defoliation. The larger workers cut and drop large sections of needles; the smaller ants dissect and store

²This shoot moth, sometimes called *Evetria buoliana* Schiff., attacks all pine species indiscriminately (70). Longleaf pine is a recognized host (188).

them. Young trees are attacked in late fall, winter, and early spring when other foliage is scarce. In the late spring, when oak leaves unfold, ants ignore the pines. The smaller seedlings defoliated by ants easily succumb to drought, but injury to those above 2 or 3 feet high is seldom fatal.

In Louisiana the leaf-cutting ants are especially common in the lighter phases of the Susquehanna, Norfolk, Orangeburg, Cuthbert, and Ruston fine sandy loams, and in similar soils containing over 60 percent sand in the surface layer. So far the Texas leaf-cutting ant has not been reported east of the Mississippi River. The northern limit of distribution appears to correspond with the southern limit of territory having an annual minimum temperature of 10° F. The nests, under bare surfaces of soil with numerous irregular reddish craters, are often found on southwestern exposures.³ Inconspicuous exits used in foraging may be over 300 feet from a nest, and entrance holes 20 feet away. This affords protection from rain and renders control measures difficult.

Thorough treatment at the proper time with the fumes of carbon bisulphide⁴ has been effective in controlling ants on national forest plantations in Louisiana and Texas at very little cost. Before the ants could reestablish themselves, the young trees had passed the fatally susceptible stage. Control measures should be applied in winter, before pines are planted, since poisons have proved ineffective during the summer.

Flower, Cone, and Seed Insects

A pitchmoth (*Dioryctria amatella* Hulst.) which infests the pistillate flowers and destroys numerous cones of longleaf pine, has been collected in Florida, Georgia, Mississippi, and Louisiana. *Dioryctria abietella* D. & S. has been reported from Florida and Louisiana in shoots and cones. The larvae of these moths can be very destructive to cones, killing many of the younger ones outright and later partially destroying the seeds. Such depredations sometimes account for the local scarcity of longleaf seed, and are partly responsible for the comparative rarity of good seed years. About a score of other insects have been reared from infested longleaf pine cones, but no extensive damage is reported.

In experimental sowings on the Osceola National Forest, pregerminated longleaf seeds have been destroyed by the larvae of the Florida harvester ant (*Pogonomyrmex badius* Latr.) and by flies belonging to the family *Phoridae*.⁵ In a study of seed

³Excavation has disclosed nests of hemispherical, interconnected chambers with flat floors and arched roofs extending 10 or 20 feet below the surface. The only food in these nests is a fungus grown on macerated leaves, cut preferably while still green, from oak or pine. An excellent nest-site indicator in some regions is dog fennel (*Eupatorium capillifolium* Small).

⁴This chemical, however, can be a fire hazard if handled carelessly. A less dangerous and equally effective fumigant is methyl bromide, which is neither inflammable nor explosive (322). At ordinary temperature and pressure it is a colorless gas, approximately 3.5 times as heavy as air, with an odor somewhat like that of chloroform. Although extreme exposure may be fatal, it can be handled safely out-of-doors without a gas mask.

Methyl bromide in liquid form can be poured into the ant tunnels in winter or early spring with good effect. It is unnecessary to stop the tunnel entrances with earth. For a colony of average size, a pound of methyl bromide applied to the central portion will eradicate or greatly reduce the ants. The larger colonies should be treated at the rate of approximately one pound of methyl bromide per acre.

⁵Wilson, Ralph R. Direct seeding at Olustee, Florida. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

predators in southern Mississippi, harvester ants removed 1,317 seeds out of the 36,000 exposed over a period of 10 days. Other insects, particularly species of fungus gnats, have damaged longleaf seeds in germination experiments.

Engraver Bark Beetles

The engraver bark beetles, *Ips* spp., are among the most destructive insect enemies of longleaf pines in the sapling and larger size classes (569). Three species of bark engravers, *Ips grandicollis* Eichh., *I. calligraphus* Germ., and *I. avulsus* Eichh., resemble the southern pine beetle (*Dendroctonus frontalis* Zimm.) in habits, manner of working, and general appearance. They can be distinguished by the conformation of the posterior end of their bodies. The *Ips* engraver beetles (Pl. 34, C and D) appear in profile to be chopped off or scooped out and armed with several minute toothlike projections. By contrast, the posterior end of the southern pine beetle has a well-rounded convex surface. The egg galleries of *Ips* are straight or star-shaped, whereas those of the southern pine beetle have a serpentine or S-shaped appearance (480). Infested trees not yet dead are easily located by their drooping and discolored needles and by the pitch tubes and boring dust or frass on the lower parts of the trunks.

Ordinarily *Ips* beetles first attack scattered pines already weakened from other causes, along with the slower-growing and less thrifty trees. However, they often kill pines among all thrift and size classes when prolonged drought, repeated fires, destructive turpentineing, and poor sites lower the vitality of old-growth forests. Evidence that fire injury increases susceptibility of the weaker trees to beetle attack is abundant. In one instance, some plots marked for thinning but left uncut in thrifty second-growth longleaf in northern Florida were accidentally burned over in April. Within 2 weeks approximately one-tenth of the trees marked to be cut had been attacked by *Ips*, and by November 65 percent were infested. In contrast, one plot from which the weaker trees had actually been removed lost only 1 tree out of 25 reserved.⁶

Ips sometimes multiply in slashings following a sudden cessation of cutting and then attack and kill a few healthy trees, but the resulting brood usually does not develop and the attack terminates. Control of *Ips* is usually left to the balance of nature. Ordinarily, infestations are too slight to justify artificial control except when large-scale logging operations are suddenly interrupted during the growing season. In severe drought, all control measures have been futile, but usually the felling and peeling of infested trees is sufficient without burning the bark. Sanitation cuttings are recommended, but it is not necessary to remove all unthrifty trees. Those which have been deserted by the insects and are merely suffering from defoliation, without infestation of inner bark, may be spared (517).⁷

⁶Osborne, J. G. Fire damage in the turpentine pine region of the Southeast. Report of extensive survey in Florida, Georgia, and South Carolina. 1932. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

⁷The condition of the inner bark, or cambium, at the base of the trees is generally a much surer guide than the condition of the needles or the top of the tree, since some of the leaf-eating beetles cause the needles to die, making it appear that the trees are attacked by bark beetles.

Southern Pine and Turpentine Beetles

One of the most destructive forest pests in the naval stores region is the southern pine beetle (*Dendroctonus frontalis* Zimm.) (295, 300, 302) (Pl. 34, A). This insect is about $\frac{1}{8}$ inch long, about the same size as the engraver beetles, and resembles the turpentine beetle, which is about twice as large. Although preferring short-leaf and loblolly, it sometimes infests pure longleaf stands. This occurs infrequently, but when it does it is likely to be a primary cause of death. The evidences of infestation resemble those of *Ips*. Drought and unseasonably warm winter weather favor its development. The broods develop during the warm months, emerging in 30 to 40 days after attack. The entire longleaf pine belt is subject to infestations, but fortunately depredations are widespread only at comparatively long intervals.

The southern pine beetle kills vigorous pines of all sizes above 2 inches in diameter. Fading foliage may appear within 3 weeks after the beginning of infestation. The beetles infest the upper and middle portions of healthy trees and the boring dust or pitch tubes on the bark may not be seen at the base until the leaves begin to fade. Fading foliage means that the trees are still a menace to their healthy neighbors, while reddish or brown foliage indicates that they are no longer dangerous because the insects have emerged.

Fire injuries in the virgin forest are not believed to foster depredations by *Dendroctonus* (297), perhaps because bark and leaves are not extensively killed. However, the beetles are known to have attacked scorched second growth (480).

The southern pine beetle infests logging slash but seldom if ever produces broods therein. Since the danger of infestation is greatest in dry periods, it is well to avoid cutting or thinning operations during drought. Indeed, logging should be delayed until outbreaks have been controlled or the drought ends. To avoid the possibility of even light mortality from bark beetles, the trees on permanent sample plots should be cut only in the dormant season.

A certain degree of natural control of the southern pine beetle has been traced to the inhibiting effects of extreme temperatures. Beal (26) summarized his study of this insect in North Carolina as follows:

"Low winter temperatures result in the death of many of the overwintering brood. Air temperatures of 10° F. cause almost complete mortality of broods overwintering in the moist phloem between bark and the wood. Sub-zero temperature is usually fatal to all stages of the southern pine beetle except the egg stage. Eggs withstand air temperature of -5° F. Occasionally pupae survived this same extreme cold. Mature adults and larvae are more easily killed by cold than inactive prepupal larvae, pupae, and young adults. Since most of the young overwinter as larvae, there is a high brood mortality beginning somewhere between 10° and 15° F.

"High summer temperature has not been found to be a natural limiting factor. The broods develop over a wide range of temperature, and in standing trees this development proceeds rapidly during the entire summer. However, in felled logs exposed to the sun during the summer months subcortical temperatures as high as 112° F. occurred, which produced complete mortality of the brood. During clear, sunny days exposed logs reached this subcortical temperature when the air temperature was between 70° and 80° F."

For effective artificial control, infested trees should be cut before the foliage turns brown. The bark should be peeled up to a 3-inch top and burned unless the logs are sent immediately to a mill or other manufacturing plant where the slabs are burned.⁸

Craighead (128) noted a symbiotic relationship between *Dendroctonus* beetles and blue-stain fungi. Each is concomitant with lowered moisture content in the trees, and beetles appear to feed on the hyphae. The fungus may be mildly parasitic or toxic, and may clog the tracheids.

The black and red turpentine beetles (*Dendroctonus terebrans* Oliv. and *D. valens* LeConte) are about $\frac{1}{4}$ inch long (Pl. 34, B). Usually breeding in stumps and logs, they occasionally infest weakened or dying pines at a point not more than 6 feet above ground, injuring but not often killing the trees. Long, half-inch-wide galleries in the inner bark result from the tunneling of many larvae. The cambium may be destroyed in broad basal patches that are later mistaken for fire scars (298).

Large pitch tubes form near the base of longleaf pines infested with turpentine beetles, but the flow of resin ordinarily drowns the beetles. Cessation of logging operations may encourage attacks on living trees and necessitate the peeling or burning of bark from surrounding stumps to destroy the broods, but in general the thrifty trees left standing after thinnings, improvement cuttings, or seed-tree cuttings, are not molested.

Roundheaded Borers

Among the organisms that contribute first to the death of injured or weakened trees and later to disintegration of the remains, the round- and flatheaded wood borers and termites are prominent. As soon as the bark of trees infested with other insects begins to die, it is subject to attack by adult sawyer borers.

A roundheaded borer, the southern pine sawyer (*Monochamus titillator* Fab.), works on all species of dying, dead, or felled pines (599, 600). Signs of infestation are the egg pits excavated in the bark. The larvae are footless white grubs, sometimes $2\frac{1}{2}$ inches long and $\frac{3}{8}$ inch thick. Their damage results from first mining the bark, then tunneling the sapwood and sometimes entering the heartwood. These boring larvae abound in stands broken by hurricanes, often damaging as much as 25 percent of the infested logs and, by perforating otherwise clear wood with large holes, reducing the lumber grade to No. 2 Common.

Deterioration of the wood in trees killed by storms, insects, fire, or lightning usually can be prevented if the logs are peeled or stored in water, or utilized promptly, during the few weeks while the grubs are still in the bark (299). Peeling or storing must be done before the larvae enter the wood, or within 40 days after the eggs are laid. During periods of greatest insect activity, mainly from February 15 to November 15, logs should not be left under conditions favoring attack. In trees felled between March 1 and October 15, egg laying will probably commence at once (599). Banking logs without skids in low, damp, swampy, or shaded places should

⁸Experiments in the physiochemical control of *Dendroctonus frontalis* on shortleaf pine were reported in 1930. Hydrocyanic acid and other poisons were injected into the outer sapwood to kill developing broods. No attempt was made to dilute solutions enough to save the life of the infested trees, although it is regarded as possible (130).

be avoided. Outside of ponds, logs should be stored in sunny locations with a free circulation of air (478).

Turpentine Borer

The turpentine borer (*Buprestis apricans* Herbst.) indirectly destroys many pine trees.⁹ The larvae feed for at least 3 years before constructing their pupal chambers near the surface of the wood, where they are metamorphosed into the adult or beetle stage. After emerging in the spring, the adults feed on pine foliage for a few weeks. During this period the beetles mate, and females deposit their eggs on the exposed or checked surface of wood (25). Checking that favors the deposition and incubation of eggs on turpentine faces results mainly from (1) fire burning off the protective coating of gum, (2) scraping which removes too much gum, and (3) dry-facing resulting from deep cuts for insertion of gutters.

The wood behind turpentine faces is often riddled and weakened by these borers, resulting in wind breakage. At one place in Florida, 62 percent of the virgin longleaf seed trees were lost in this way during the 12 years following turpentineing (127). The attacks of the turpentine borer increased with the severity of chipping. The insects infested 4 percent of the experimental French faces, 27 percent of the narrow American faces, 83 percent of the standard faces on a national forest, and 95 percent of the more heavily worked faces on adjacent private land (Pl. 35). In second-growth longleaf it is possible to prevent nearly all such damage by using conservative turpentineing methods and protecting worked faces from scorching.

Termites and Other Wood-Destroying Insects

Most pine wood is susceptible to destruction by termites, but the resin in lightwood (fatwood) from the butt of longleaf pine repels them. Thus, stakes made of resinous longleaf remained unattacked by termites after being exposed to them in the ground in Texas from 1913 to 1922. Insects, like termites, that prefer to live in dead wood usually find sufficient nesting and food material without attacking green wood. Hence they assist in the disposal of plant debris and do so little damage that they can be disregarded in forest protection.

Minor damage to longleaf pine is sometimes caused by the ambrosia beetle (*Platypus flavicornis* Fab.) or a large borer (*Chalcophora virginensis* Dru.), both of which penetrate sap- and heartwood alike (68).¹⁰

BROWN-SPOT NEEDLE DISEASE

The fungus causing the brown-spot needle disease (*Scirrhia acicola* (Learn.) Siggers) has occurred in the South since at least 1876 (272). Although it is reported to infect some 24 host species or varieties of pine, of which 10 are native to the Southeast, it is by far the most serious on longleaf pine in the grass stage, especially on unburned tracts. The hybrid Sonderegger pine is severely attacked on some sites.

⁹Flatheaded borers are particularly destructive in the naval stores region. The turpentine borer should not be confused with the turpentine beetles. Burke (68) gives a key to the genera of *Buprestis* larvae.

¹⁰Snyder (514) has catalogued insect damage to forest products according to the character of defects caused, such as pinholes, grubholes, and powder-post. Powder-post beetle damage to longleaf pine trusses in the roof of the White House in Washington was traced to *Hexarthrum ulkei* Horn, an insect of the family *Cossonidae* (515).

Symptoms and Behavior

The first symptom of brown spot is a small, light, gray-green circular spot which changes quickly to brown and later encircles the needle in a narrow band. Death of the apical portion of the needle results from multiple infections rather than an isolated girdling lesion. Vascular tissues are not invaded (272). Certain so-called bar spots are small lesions with a yellow margin. Frequently found on foliage several feet above ground, they appear to be unfruitful ascosporeous infections of brown spot.

As scattered foliar lesions increase, they divide the long needles into three zones of infection: (1) the green basal part of young needle tissue nearly free from spots, (2) a spotted middle section where lesions alternate with green tissue, and (3) an outer brown zone of older dead tissue. The disease is often fatal to seedlings less than 18 inches tall, and seriously retards others up to 3 or occasionally 5 feet. Foliage up to 8 feet or more usually bears only scattered spot infections.

There are two types of spores: conidia, dispersed mainly by splashing rain, and ascospores, dispersed by air currents. The first are more abundant, are produced at any season of the year in a sticky matrix, and are not transported by wind. Normal winter temperatures are too low for much spore production and summer showers are too short to allow the fruiting bodies to open and distribute their spores. Two or more rainy days are needed for abundant dissemination. The windborne ascospores, produced mainly in winter and spring, and only on withered parts of needles, are relatively scarce. Usually they are abundant only in heavily infected, dense stands of seedlings. In the presence of ascospores, a low degree of reinfection may appear on burned areas in the spring following a winter fire.

The weakest seedlings in the grass stage respond quickly to favorable weather, often producing a few new needles during warm winter weather. The more vigorous a longleaf pine seedling, the later it begins growth in the spring and the faster its needles develop once they have started. This relieves dominant seedlings of some disease effects. In one instance seedlings that had distinct, white, scaly winter buds did not put forth new foliage until April, whereas the poorest seedlings, devoid of bud scales, did so about the middle of February. Foliage of the backward seedlings was brown-spotted before disease was visible on the vigorous ones, and the poorest seedlings suffered one complete cycle of the disease before the best seedlings were infected at all. The foliage of the strong seedlings developed so much faster than that of the weak ones that by the middle of June the average length of the needles on the best seedlings was greater than that of the needles on the poorest, despite the fact that the latter were two months older (594). Brown spot is a starvation disease that normally approaches its climax slowly for several years. During this period the leaf-killing spots become larger and more numerous until nearly all needles have turned brown. The disease tends to become progressively more severe in the unburned portions of a forest. The damage to needles in one growing season is reflected in decreased growth and general unthriftness the following season, so that, for an indefinite period of years, brown spot prevents active and vigorous growth. Numerous small and stunted seedlings remain half hidden by grass while they gradually become weaker from premature shedding of diseased needles. Thus the dis-

ease may continue unnoticed for many years. The longer seedlings are kept in the grass, the less their chance to survive. By delaying height growth many years, brown spot contributes indirectly to low survival, but other factors are more often the direct cause of death.

Height Growth of Diseased Seedlings

Whether blighted or not, longleaf seedlings never start vigorous and active height growth until they are about one inch in diameter at the ground and two inches in height. Brown spot and other injurious agencies delay this development. Within a given size class, the degree of defoliation largely controls the rate of growth. Complete defoliation reduces annual height growth in the next season to about a seventh or less of that of comparable seedlings protected by spraying. Figure 48 shows how the percentage of infections affects the height growth of seedlings in different height classes (501). This chart can be used in estimating the approximate length of time it will take a diseased stand in the grass stage to reach breast height. Such an estimate should be based on dominant seedlings likely to survive, and on the average percentage of infection. If there are enough dominant seedlings, an intensification of the disease among the intermingled weak seedlings¹¹ may help rather than harm the stand.

Freedom from serious defoliation may account for the relatively early, active height growth sometimes observed in a stand of longleaf seedlings (500). On certain good sites numerous seedlings emerge so promptly from the grass as to escape heavy infection. However, there is considerable evidence that the long-continued absence of fire will foster brown-spot infection to a point where it may reach epidemic proportions.

Heavily diseased areas result from multiple infections with conidia, due to rain.¹² Severe infection leads to early stunting of seedlings, and to the eventual death of the least resistant ones by preventing photosynthetic activity while still in the grass stage. Most of the fatalities are inconspicuous and often pass unnoticed. Ordinarily, at least three successive defoliations are required to kill a seedling.

Seedlings are subject to brown spot as soon as fascicled needles appear, and serious dwarfing is largely confined to pines less than 6 inches tall. In crowded stands of natural reproduction, sometimes containing 200,000 to 300,000 seedlings per acre, the presence of dense masses of susceptible foliage greatly increases the intensity of infection.

The healthy condition of the taller seedlings and saplings might result from the scarcity of spores at the height of their foliage rather than from resistance of the hosts. Yet the fact that certain individuals still in the grass also seem to be nearly immune suggests some intrinsic physiological capacity for resistance (Pl. 15). Immunity seems to be correlated with vigorous height growth. Resistant seedlings, saplings, and trees may bear, in addition to brown spots, certain bar-spot lesions which

¹¹Sometimes the dominant seedlings become more heavily diseased than the backward ones. This condition is found under certain environments, as indicated in the following section.

¹²It has been asserted that during rainy periods cattle spread the spores from heavily diseased stands on unburned areas to burned areas relatively free from disease, but proof of this is lacking. Most of the spread is apparently due to rain splash.

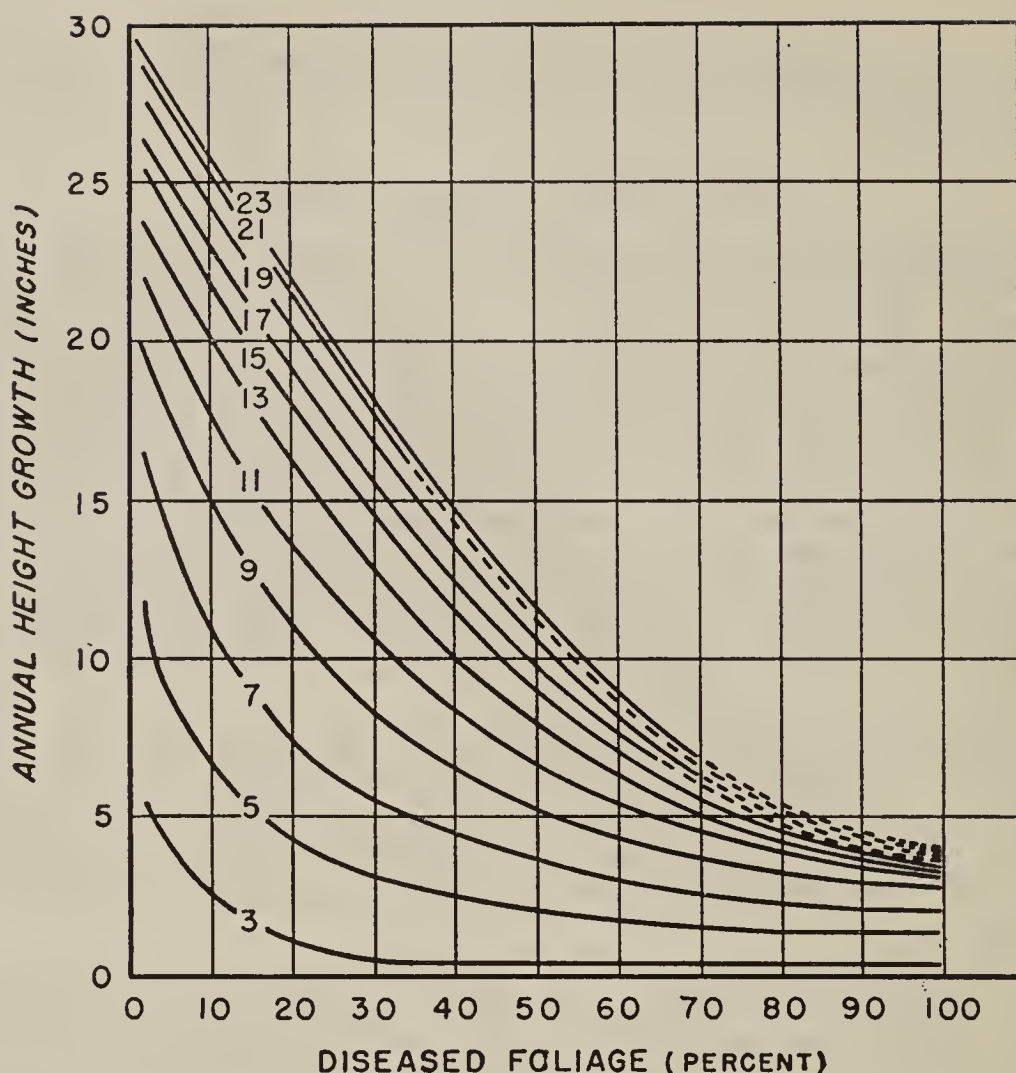


Figure 48—Effect of brown-spot needle disease in retarding height growth of longleaf pine seedlings. Figures on curves show initial height classes in inches; broken lines are harmonized extrapolations. (After Siggers)

indicate arrested fungus development following infection. For example, in a laboratory test it was found that the resin content of brown-spotted tissue was 9.3 percent from seedlings, 16.5 percent from saplings, and 20.9 percent from bar spots of saplings. This suggests that the resistance of saplings and certain seedlings is related to ability to produce resin and thus limit the extension of the fungus (574).

Effect of Environment on Disease

Environmental factors may also account for the immunity of some seedlings while in the grass stage. Thus in dense, heavily infected stands, brown spot is most destructive on those seedlings in which the foliage just overtopping the grass has become exposed to infection from all sides, and least destructive on seedlings with foliage hidden in the grass. Native grasses and other vegetative cover offer a partial

shield against severe infection. The more exposed seedlings, whether weak or strong, tend to be heavily diseased (498). The smaller seedlings, being partially sheltered by grass, may be much less infected. This condition is usually found under thick herbaceous ground cover, the disease injuring the larger seedlings most severely and therefore producing a leveling effect that is undesirable because it tends to delay an early expression of dominance.

On the Choctawhatchee National Forest, the least infection (5 to 7 percent of the foliage) was found in virgin longleaf stands, in pastures sprayed with fungicide, and in scrub oak stands where the litter was burned. Medium infection (13 to 15 percent) occurred in undisturbed stands of scrub oak, and heavy infection (30 to 31 percent) in the most open places, such as plowed areas, pastures, and experimental clearings.

Control Measures

Control of brown spot by repeated spraying with Bordeaux mixture is practicable in nurseries (601),¹³ but not in extensive field operations. Nevertheless, according to Hepting (275), where the disease is abundant spraying sometimes spells the difference between success and failure of a plantation or area of natural reproduction. Applied to heavily infected areas, fungicides restore and maintain a normal rate of seedling development (Pl. 25, B). Satisfactory but not necessarily complete control by spraying requires two applications a year, the first about the middle of May, the second in November, during the first two seasons in the field. Such treatments can be expected to promote active height growth among enough seedlings to produce a satisfactory sapling stand.¹⁴

The extent to which fire checks the progress of brown spot is of practical importance. There are no accumulations of dead and infected foliage on longleaf seedlings where fires have been frequent, because the dry, easily ignited dead foliage is destroyed. Foliage killed but not consumed by fire is free from inoculum because any temperature fatal to leaf tissue also kills the fungus. Usually relatively few lesions occur above the withering heat of flames, even in light fires, so that fire is an effective sterilizing agent.

A single fire greatly reduces the disease in the first growing season that follows, and often to a lesser extent in the second. The duration of the sanitary effect depends mainly on coverage of the area burned, the size of the tract, weather conditions, and the amount of wind-borne inoculum. Typical border-line reinfection in crossing a 100-foot annually burned fire line in the midst of an epidemic area was found by Verrall (575) to be as follows: on both sides of the fire line, about 15 percent; on

¹³The most desirable mixture contains 3 pounds of powdered copper sulphate, 3 pounds of fresh hydrated lime (high quality, 300- to 400-mesh fineness), and 50 gallons of water. A good commercial "spreader" or "sticker" should be added at rates recommended by the manufacturer. If spraying is started June 10 to 15 it should be repeated at intervals of 4 to 6 weeks. If past experience indicates that brown spot is severe, an interval of 4 or 5 weeks is better than 6 weeks. The last spray should be applied a few days before lifting starts in the fall.

¹⁴The acre cost per treatment will approximate 3 man-hours plus 25 cents (pre-war prices) for the fungicide. Either Bordeaux mixture (4-4-50) or lime sulphur (1-50) can be used. Casein spreader, at 2 pounds to 50 gallons of spray solution, is recommended with either chemical. Certain soaps are satisfactory adhesives and may be used with Bordeaux mixture but not with lime sulphur.

both 5-foot margins of fire line, 4 percent; and in the central part, 2 percent. Such a pattern results from sterilization by fire followed by reinfection from rain-spattered rather than wind-borne spores.

Reduction of brown spot often permits the foliage to survive through the second growing season, a condition that is always essential to the optimum development of seedlings and usually to prompt emergence from the grass. Chapman (112) has noticed that foliage must have 2 to 4 periods in which needles are retained in healthy condition for 2 consecutive years in order to remain vigorous and enable a seedling to shoot up out of the grass stage on schedule. In general, the sanitary effect of a fire varies inversely with the amount of wind-borne spores and directly with the size of the burned-over tract.

To avoid heavy mortality from burning, control is desirable before infection reaches 35 percent of the foliage in midwinter. The percentage of infection can be determined by estimating the percent of dead foliage on 100 representative seedlings and averaging to obtain a figure for the stand. Fire is the principal means of controlling the disease in the field.

On areas set aside for growing timber, where the seedlings are established but not yet above the grass, controlled winter burning is recommended at about 3-year intervals until a sufficient number start height growth. Where the intensity of the disease can be correctly appraised, longer intervals may be practical. A 4-year interval, however, is usually followed by too much reinfection for maximum thrift of seedlings. Plantations should not be burned over before the beginning of the second growing season in the field. The best time to burn is in late winter, just before spring growth starts. Along the Gulf Coast this is from mid-February to mid-March.

OTHER DISEASES

Diseases of Cones

The fungus *Cronartium strobilinum* (Arth.) Hedgcock and Hahn, formerly called *Caeoma strobilina* (Arth.), first noted on longleaf pine by Arthur (11) in 1906 near Palatka, Fla., attacks first year cones. In 1919 it was observed that this disease infected from 25 to 90 percent of the cones on many trees. *Cronartium strobilinum* usually penetrates the entire cone, which then swells up to the size of a mature 2-year-old cone. Infected cones are brick-red, whereas normal ones are green, and the scales are cemented and show no tendency to separate when dry.¹⁵ They die by autumn and usually drop from the tree, only an occasional stunted one remaining.

Rust Cankers

Rust-canker disease, caused by the native fungus *Cronartium fusiforme* Hedgc. and Hunt, has attracted increased attention in all the Gulf States during recent years. Its increased prevalence in longleaf pine trees may be ascribed, in part at least, to the encroachment of loblolly, shortleaf, and slash pine on lands originally occupied

¹⁵So far as is known, slash is the only other pine attacked by *Cronartium strobilinum*. Chestnut oaks, live oak, and sand live oak, which are found in close association with the infected pines, are possible alternate hosts (273). These oaks are subject to many diseases, and cone crops may be completely destroyed in their neighborhood.

by longleaf. The spread of these associated pines, which are less resistant to disease, may increase the amount of inoculum available to infect longleaf. Rust cankers, however, are not yet a serious problem far inland or west of the Mississippi River.

The fungus causes abnormal swellings, galls, or cankers. On main stems or branches of pine seedlings, these are spindle-shaped; on larger trees, the infected portion may be a large sunken area. The disease does not pass from one pine tree to another. Various oaks, many of which are common on longleaf lands, serve as alternate hosts to complete the life cycle of the fungus. Only a few instances of severe rust-canker infection, i.e., on more than 10 percent of the trees, have been found in natural stands of longleaf reproduction. Material damage results only from cankers on or close to the trunk. If economically feasible, cankered branches should be cut out to reduce fatal trunk-girdling infections.

An intensive survey of 16 southern nurseries in 1938 showed that more than 25 percent of the slash pine but only 2 to 5 percent of the longleaf seedlings were infected with *Cronartium fusiforme*. The most effective control in and near nurseries is to remove the more susceptible oaks,¹⁶ cut out cankered trees, and spray nursery seedlings. If longleaf rather than other pines are planted on areas where rust-susceptible oaks are common, control measures may be unnecessary (275).

Heart Rots

Certain saprophytic fungi or heart rots, such as *Polyporus* spp. and *Trametes pini*, commonly called "red heart," are often responsible for the weakening and resultant wind breakage of longleaf seed trees, especially those that are overmature. Where a dead limb falls off, leaving a small punky hole, a large shelf-like fruiting body eventually develops. The heartwood of such trees is reddish, brittle, and full of small channels lined with white mycelium (263). Trees containing red heart should be utilized before they are seriously decayed and too much of their lumber is degraded.

Decay is most prevalent in trees that have grown close together, but ordinarily it does not become a serious factor in longleaf pine until the trees are well over 100 years old. Hence, decay is not yet a serious problem in second-growth stands. Basal scars, so common on old-growth trees, start in most instances from persistent flames in adjacent pitchy fragments of heartwood, or from bruises suffered in logging. In the virgin forest, decay caused by fungi living mostly on dead wood is often the primary but seldom the final cause of death. It gradually weakens the trees, predisposing them to deep fire scarring, sometimes followed by insect attacks and finally windfall.

ANIMAL DAMAGE

Among the creatures capable of exerting a material influence on longleaf pine reproduction are cattle, horses, goats, sheep, hogs, rodents, and birds. Nearly everywhere in the longleaf belt livestock have open range, but damage from the larger

¹⁶Black oaks are much more susceptible than white oaks. Water oak (*Quercus nigra* L.) and willow oak (*Q. phellos* L.) are highly vulnerable. Other oaks in descending order of susceptibility are laurel oak (*Q. laurifolia* Michx.), blackjack oak (*Q. marilandica* Muenchh.), bluejack oak (*Q. cinerea* Michx.), southern red oak (*Q. falcata* Michx.), and turkey oak (*Q. laevis* Walt.).

animals is negligible except where the range is overstocked. Sheep and goats injure longleaf buds and deform the larger seedlings, while hogs strip and chew the inner bark of seedlings, mainly those in the late grass stage. Rodents and birds eat many seeds. The total damage by each of these agents is not measurable, but unquestionably longleaf suffers from such depredation more than other southern pines.

Hogs

The damage inflicted upon longleaf pine regeneration by "razorbacks" or piney woods range hogs (Pl. 36) is much greater than that caused by the larger grazing animals. Seedlings, remaining close to the ground for several years, are subjected to severe perennial damage beginning with the second year. All sizes are attacked, but the largest in the grass stage are most palatable to hogs (Fig. 21), which persistently root up the seedlings and often return to a spot annually to consume those missed in earlier raids, until in perhaps 3 to 5 years after seed germination there are few or none left. Such casualties often exceed those from promiscuous burning.

Hogs are attracted to the luscious cortex of the main taproot. Usually the thick bark is chewed off at and below the ground line so that the seedling is partly or completely girdled, mangled, torn loose, or broken off. The lateral roots of seedlings are not touched, even though the excavation may extend to 16 inches. The larger laterals of saplings, however, are more attractive to hogs than the small roots. Occasionally hogs dig long trenches, sometimes reaching 35 feet, to get at the roots. The succulent inner bark is especially relished in the spring, when other foods such as oak mast and bulbous or tuberous roots are scarce, when high water has driven the animals from hardwood bottoms and swamps, and when the surface soil in the piney woods is soft enough for seedlings to be readily uprooted.

Hog damage is usually concentrated near rural settlements and on the less well-drained longleaf soils. There are no accurate appraisals of hog damage for extensive regions, because much evidence disappears in less than a year, particularly if the seedlings are severed at the ground and killed.

Little or no hog damage is manifest in the dry sand-hill forests of Florida. The moister flatwoods areas present a different picture. Hogs have been observed to kill 8,320 2-year-old longleaf pine seedlings per acre at rates estimated at from 200 to 400 per day (383). This rate was doubled or tripled over short periods where the stand was readily accessible and rooting easy. Thus a single marauder might obliterate an acre of planted pines in one day. In another case, hogs were observed to kill about 60 percent of a well-stocked stand of longleaf pine in the grass stage over a period of several months. In this instance 10 percent of the surviving seedlings were damaged by chewing of the bark and cambium layer above the soil.

An open-range survey on the De Soto National Forest in Mississippi revealed that hogs attacked nearly one-third of the longleaf pine saplings 2 to 9 inches in diameter, but did relatively little damage. Greater harm was done to saplings 5 to 15 feet high. Most seriously injured were the seedlings between 2 and 48 inches high; among these, from 9 to 44 percent were attacked in different districts.

Consumption of seeds by hogs is usually far less serious than injury to seedlings. However, hogs sometimes devour longleaf pine seeds almost as soon as they

fall, leaving only a few to germinate. A study¹⁷ of such damage in unprepared seed spots in southern Mississippi disclosed that in 10 nights 1 old sow with 6 pigs removed 3,454 seeds out of 12,000 available. Of those taken, 61 percent were from the burned and 39 percent from the unburned portion of the area.

Fencing is, of course, the best way to keep hogs out of the forest. It has been demonstrated that on areas partly fenced for experimental purposes, like the Roberts plots, seedlings must be protected for at least the first 5 years (290) or until they reach 10 feet high. Since hogs often travel 15 miles to obtain sustenance, drift fences are useless. Woven-wire fences are difficult to keep in repair, especially in swampy areas. An electric shock fence is relatively inexpensive to construct, but difficult to maintain because grass grows up around the fence and rain-soaked stalks tend to drain off the current. The surest safeguard is a well-constructed fence of high-quality woven wire, supplemented by a watchful guardian to expel hogs that trespass.

Cattle and Horses

Cattle and horses ordinarily injure longleaf seedlings seriously only in the seedlings' first year and then in proportion to the extent of overstocking on the range. Damage from uncontrolled range burning, indirectly resulting from cattle grazing, is likewise most serious in the first year. This damage, in fact, greatly exceeds that caused by cattle. Cattle avoid longleaf seedlings as soon as the typical luxuriant plume of foliage is formed preparatory to active height growth.

Surrounded by native grasses, all yearling pines are not killed by cattle under the moderate stocking (about 1 head to 10 acres) found in the longleaf belt. On closely grazed spots of carpetgrass, however, the feeding and trampling usually kills all seedlings. Hence, it is advisable to graze few cattle or to keep livestock away from valuable pine reproduction throughout its first year.

The best policy (100) is light grazing during the first summer after the establishment of longleaf seedlings, increasing slightly the second year, and materially thereafter. Moderate stocking with cattle may remove about 25 percent of the fire hazard. Further reduction of the inflammable litter must be accomplished by burning. Range fires in winter remove surplus fibrous roughage, thus making spring herbage more accessible. Burning should be so arranged that the resulting spring concentration of livestock will do least harm to the forest.

Sheep and Goats

Sheep and goats, unlike hogs, do not usually molest longleaf seedlings until the pointed bud is formed. These animals browse and nip buds from the terminal shoots of larger seedlings. Above 3 or 4 feet the buds are again relatively safe, but occasionally, a sheep or goat may bend down saplings to get at their buds. The smaller seedlings in the grass stage are likewise relatively safe, the damage from trampling being negligible except in long-established bedding sites. Indirect harm to the pines, however, results from compaction of the soil.

¹⁷Watkins, Allan G. Destruction of longleaf pine seeds by mammals at the Harrison Experimental Forest, Miss. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

Sheep may attack longleaf pines at any season of the year if the buds are at least 0.4 inch long. About three-fourths of the buds are removed from October to April. Little reduction in height results from removal of a single terminal bud from a thrifty pine, because during active growth it is promptly replaced by an adventitious bud. Both natural and substitute terminal buds, however, may be broken off repeatedly on areas heavily stocked with sheep.¹⁸ Many of the broken buds may not be succeeded by dual leaders, and crooks in stems grown from side buds are slight. Hence, in time, early stem deformity will be completely obliterated.

Sheep damage to longleaf pine has been studied on the Leaf River district of the De Soto National Forest, Miss. One sheep to each 12 acres was admitted to a range of 1,300 acres of regeneration, with all other stock excluded. Within the tract the sheep had access to seedlings 2 to 48 inches tall but were excluded from seedlings on small, fenced sample plots. In 2 years 83 percent of the unprotected seedlings were injured by removal of terminal buds. Mortality from disease and grazing amounted to 2.3 percent in the ungrazed sample plots, and 4.6 percent in the area grazed by sheep. Seedlings up to 40 inches high were most affected, the damage being greatest in the smaller- or medium-size classes. Thus the loss in height growth in 2 years averaged about 20 percent; for trees from 10 to 24 inches tall, it was 40 percent. These tests showed that sheep should be excluded from longleaf regeneration areas until the land is reasonably well stocked with seedlings 40 inches or more in height.

A more extensive survey of grazing damage covering 23,640 acres of longleaf pine open range on the Leaf River district showed the following results: of 3,485 longleaf seedlings examined, the proportion mutilated by sheep ranged from 4 percent on one grazing unit to 92 percent on another, averaging 56 percent. An average of 47 acres of range was available to each animal. Of the 705 saplings 5 to 15 feet high on sample areas, 28 percent bore substantial marks of earlier injury by sheep. Among 445 dead seedlings (2 to 48 inches high), fire and sheep together destroyed 58 percent, hogs 31 percent, rust canker 6 percent, brown spot 4 percent, and mechanical agents 1 percent (Pl. 33, A).

Rodents

Unlike other southern pines, longleaf seedlings are rarely injured by rabbits, but the seeds may be taken in quantity by other rodents. Some germinated seeds have been retrieved from the burrows of mice. Not usually a predator in open woods, the gray squirrel takes longleaf pine seeds near creek bottoms if acorns, hickory nuts, and blackgum seeds are not abundant.¹⁹ Such squirrels do not hoard seeds as in the North, but consume them immediately. When the cone crop is light, squirrels take as much as 35 percent of the seeds.

The pocket gopher is a recognized enemy of small longleaf pines, gnawing the roots and pulling the seedlings bit by bit into his burrow. Seedlings too firmly anchored to be removed suffer serious mutilation or immediate loss of roots. Those

¹⁸Gerhart, George A. Initial report on livestock damage to pine reproduction on the open range of the De Soto National Forest. 1941. U. S. Forest Service, Region 8, Atlanta, Ga. [Unpublished.]

¹⁹Watkins, Allan G. Biological studies at Bogalusa, La. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

large enough to have started height growth usually escape fatal injury. Mounds of fresh soil are the most conspicuous evidence that a given area is infested with pocket gophers. The gopher (*Geomys floridanus*) known in western Florida as a "salamander," is often responsible for the annual loss of 1 to 2 percent of planted seedlings. *Geomys breviceps breviceps* has caused much havoc in Louisiana plantations.

Gophers can be destroyed with poisons such as millo maize treated with strychnine alkaloid—1 part poison to 20 parts corn. Underground runways may be found by probing near the mounds, and a tablespoonful of poison is sufficient for each. Poisoned holes should be stopped with earth. As the gophers are believed to close all openings made in their tunnels by intruders, the absence of this response is evidence of effective control. During the spring of 1938, about 94 percent eradication was achieved on 2,625 acres in the Kisatchie National Forest at a cost of 13 to 20 cents per acre.

In a study of pine seed losses in southern Mississippi²⁰ the following predators were caught with longleaf seeds as bait: cotton mice (*Peromyscus gossypinus gossypinus* LeConte), Merriam harvest mice (*Reithrodontomys humulis merriami* Allen), cotton rats (*Sigmodon hispidus hispidus* Hay & Ord.), and southeastern flying squirrels (*Glaucomys volans saturatus* Howell). All the cotton rats and harvest mice were found on an unburned, open, grassy area. In an experiment covering 10 nights, only 172 out of 36,000 available seeds were taken by these rodents. Possibly this experiment was made when the rodent population was at a low ebb, although 7 years of trapping failed to reveal any evidence that rodent numbers are subject to any appreciable changes in the Gulf Coast region.

Birds

Flocks of song and upland game birds often prevent natural reforestation of longleaf pine. Where migrating flocks gather, birds eat more pine seed than do rodents. In the forest, their depredations tend to be concentrated on open grassy areas, particularly those recently burned over (Pl. 33, B).

The principal birds that eat longleaf seeds on forest land are: southern meadowlark (*Sturnella magna argutala* Bans), mourning dove (*Zenaidura macroura carolinensis* L.), bobwhite quail (*Colinus virginianus* L.), cowbird (*Molothrus ater* Boddaert), rusty blackbird (*Euphagus carolinus* Muller), Brewer's blackbird (*Euphagus cyanocephalus* Wagler), and redwinged blackbird (*Agelaius phoeniceus* L.). Many of these, and other birds, also feed on nursery seedbeds. A large flock can virtually ruin a small pine nursery in a few hours, or entirely consume the seed shed in a forest in a good seed year if drought delays germination (590, 594).

In cold weather, when insects are scarce, birds subsist largely on seed. Thus, examination of the stomach contents of meadowlarks showed that not until there was a sudden drop in temperature, followed by rain and high winds, did pine seed constitute 75 percent or more of the food consumed. Bobwhite quail examined in December were crammed with pine seed. Mourning doves eat longleaf seeds consistently, while blackbirds show a marked fondness for seed found on burned areas.

²⁰Watkins, Allan G. Destruction of longleaf pine seeds by mammals at the Harrison Experimental Forest, Miss. 1935. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

Burleigh (69) reported that "examination of the contents of stomachs showed that pine seed was always eaten when it was available, but since other seeds and insects were never left untouched, the pine seed rarely exceeded 50 percent of the total food eaten. This was sufficient, however, for the birds to prevent the development of most seedlings on any area in which they were feeding for they invariably remained in compact flocks that overlooked little material acceptable as food. After the seed had germinated it was still in danger of being severely injured, if not destroyed, for the endosperm and seed coat clinging to the cotyledons were as acceptable as the seed itself. In this connection it was interesting to compare the damage done by the blackbirds with that done by the meadowlarks late in winter. When taking the endosperm with their short, conical bills the blackbirds merely clipped off the tips of the cotyledons; whereas the meadowlarks, having relatively long, stout bills, tended to cut off the entire seedling near the root collar."

The dependence of some birds on longleaf seeds in late fall and early winter seems to account for much of the recent difficulty in reproducing the species by purely natural means. Formerly, extensive areas were burned over every year, so that birds could find all the seeds they desired without intensive feeding on any one spot. At present, however, seed trees are less plentiful and birds concentrate on restricted burned areas in order to get their fill. The best opportunity for regeneration appears to come in those years when the natural seed supply is sufficient to feed all the predators and still leave enough for a crop of seedlings. Chapman (106), for example, notes that in La Salle Parish, La., the most successful longleaf reproduction occurred in years of heavy seed crops. According to some students, however, artificial direct seeding should be done in years when seed is not abundant and birds correspondingly scarce.

Many insectivorous birds benefit pines by consuming the larvae of bark and shoot-boring insects (84). Most woodpeckers are beneficial. The yellow-bellied sapsucker (*Sphyrapicus varius*), on the other hand, is reported (360) to attack longleaf pine throughout its range, sometimes killing young trees and disfiguring others. Protruding girdles may be formed and the resultant internal blemishes keep the lumber out of finishing grades.

Comparison of Predators

The problem of loss of seeds to birds, animals, and insects has been thoroughly investigated on the longleaf lands of southern Mississippi. The activities of four classes of seed thieves were compared on each of three cover types or habitats in a cut-over forest. Table 43 shows the loss of seeds on burned and unburned portions of each cover type to each class of predators. Birds took more seeds, either pure or poisoned, from the burned than from the unburned areas. Of the unpoisoned seeds taken from the unburned areas, hogs accounted for 56 percent, ants 33 percent, birds 8 percent, and rodents 3 percent; of similar seeds taken from the burned areas, birds accounted for 42 percent, hogs 34 percent, ants 19 percent, and rodents 5 percent.

The results on the burned areas were in the main confirmed by another study in the same forest extending over 25 days. Pine seeds were placed on prepared surfaces or denuded spots, half of which were limed to facilitate identification of predators

through their tracks. Here birds took the most seeds, 34 percent, largely from the open grassy area; hogs were next, taking 21 percent, all from the scrub oak area; rodents removed 2 percent from oak and pine stands; and ants, working in all habitats, removed 2 percent.

Table 43.—Losses of longleaf pine seed to different predators in 1,000 seed nights on cut-over land in southern Mississippi¹ (After Watkins)

Cover type	Unpoisoned seeds taken by—					Poisoned seeds taken by—				
	Rodents	Ants	Birds	Hogs	Total	Rodents	Ants	Birds	Hogs	Total
	Number									
Longleaf pine timber:										
Burned	0	29	10	0	39	0	36	4	0	40
Unburned	0	23	0	0	23	2	35	2	0	39
Scrub oak:										
Burned	26	41	35	178	280	0	41	16	383	440
Unburned	10	33	10	214	267	16	39	1	229	285
Open grassy area:										
Burned	2	29	173	0	204	3	26	57	0	86
Unburned	0	69	20	0	89	5	42	21	0	68
Totals:										
Burned	28	99	218	178	523	3	103	77	383	566
Unburned	10	125	30	214	379	23	116	24	229	392

¹A "seed night" is a unit of exposure: one seed exposed for a 24-hour period. The investigation was based on 1,000 seed nights for untreated seeds and 5,000 seed nights for poisoned seeds. As all seeds removed by predators were replaced daily, the above figures are comparable on the basis of 1,000 seed nights. Actual observations covered 10 days in the fall of 1934. Marauders were identified by tracks, poisoning, and trapping. The poisons used were strychnine sulphate, barium carbonate, potassium cyanide, thallium sulphate, and arsenious acid, each dissolved in a sugar solution. The hogs were 1 old sow and 6 pigs.

Control of Predators

On the whole, protection of longleaf pine forests from the trampling, browsing, or marauding activity of domestic and wild animals is still unsatisfactory. The relatively light damage from cattle, horses, and mules may be ignored, or it can be partially controlled by winter fires to freshen spring forage in certain designated spots, or by drift fences, or possibly by herding to remove the animals from the unimproved forest range. Ordinarily it is unnecessary to completely exclude these animals by fencing. It is imperative, however, that damage to longleaf seedlings from hogs, sheep, and goats be reduced, or eliminated where such animals are abundant, by good fences and patrol of the woods in dangerous seasons. Little can be done to protect seeds and seedlings in the forest against birds and rodents. Song and game birds eat numerous injurious insects, and are such desirable neighbors that control measures are difficult to justify. Even certain hawks, which farmers are prone to shoot, should be spared in order to hold the forest rodent population within reasonable bounds.

CLIMATIC INJURIES

Drought, wind, and lightning injure forests. Drought is hard on seedlings and on the smaller trees in a crowded stand. Lightning usually spares the smaller trees and strikes the larger, more dominant individuals. Wind may break the weaker trees, especially those recently exposed by the removal of neighbors. Tornadoes often

raze narrow strips of forest, wrecking nearly all trees regardless of size or development. Drought, wind, or lightning often weaken or maim trees so that they are susceptible to the attacks of insects and fungi and later may succumb to windfall. More often than not, longleaf seedlings or trees die from a complication of causes rather than from a single cause. Death in the forest from old age is rare, as destructive agencies almost always strike first.²¹

To appraise and understand injuries to trees by certain climatic agents the trees' normal habits of needle shedding must be known. Normal browning of longleaf needles occurs in early September each year, but most of the discoloration soon disappears. Saplings lose some foliage from lower branches that are about to die through natural pruning, and all trees lose their 3-year-old needles (280). The needles are shed at about the same time that deciduous trees drop their leaves. Because new needles develop on growing shoots continuously between March and September, the needles of any one year vary in age and do not all mature and drop at the same time. A noticeable needle fall occurs every month of the year, but the heaviest fall begins in July and continues through October. The average persistence of needles is about two years, the majority falling early in their third year. Needles of the current year are usually easy to distinguish, last year's needles being slightly darker, less glossy, and usually about an inch longer. Leaf fall induced by external causes is spotty and relatively independent of the age of needles and branches.

Effects of Drought

Droughts cause serious physiological complications in forest trees. The drought that began in the spring of 1931 and continued into the summer of 1932 affected some 10 million acres of forest in the naval stores region. The sequence of results as listed by Cary (82) was as follows: (1) subnormal rainfall, (2) dry soil, (3) subnormal growth, (4) dry facing, (5) weak trees, (6) insect damage, (7) fire weather and fire damage, and (8) after effects, including mortality. In the South such damage has varied with the species. Slash pines are far more susceptible than longleaf to dry face and death as a result of drought.

Damage, of course, depends on the duration and severity of the drought. Drought lasting from 3 to 8 months and resulting in only 20 percent normal rainfall encourages depredations by *Ips* or other beetles, and increases the extent of their damage. Greatest damage may be expected on areas both burned and turpented, and in trees showing an abnormally narrow ring of wood growth for the current year.

The direct and indirect effects of drought also depend on soil and timber conditions. Thus, trees on poor sites, such as gravel ridges or low flats with an underlying impenetrable hardpan, suffer most from drought and, of course, turpented timber is more susceptible than round trees. Forest fires cause greatest damage during severe drought. The main effects during the following season are insect attacks, reduced formation of summerwood, and reduction of gum yields 10 to 50 percent.

²¹Chapman (98) describes one veteran longleaf pine as follows: "Still alive, this battle-scarred veteran of 38 inches' diameter was found to have required 50 years to increase a bare inch in size, while the last 10 inches in diameter represented the growth of 190 years. This tree was possibly 400 years old. The ordinary limit of age of this species is 300 years, and at that age it can be expected that only one or two trees will survive of the original stand for every 20 to 40 acres of timber."

Probably 90 percent of the damage caused by the drought of 1931-32 was traceable to burning and subsequent insect attacks. Slash pine sustained the heavier losses, the longleaf being better able to survive severe scorching.

Cary (84) reported, on the basis of 200 slash and longleaf pine trees in Georgia, that through the spring of 1932 yields of gum were abnormally low from a large part of the timber in the drought district, but with the return of normal weather in the fall, yields improved. Fires in the wake of droughts may also affect the quality of naval stores products. Decline in rosin grades, owing to discoloration from charcoal and other impurities, accompanied the low gum yields of 1932. The following figures from Georgia illustrate the 1932 reduction below the previous year's gum output: May 15 to June 30, 29 percent; July, 20 percent; August, 5 percent; the remaining 12 weeks of the season, 8 percent. Thin bands of summerwood for 1931 and springwood for 1932 were surrounded by summerwood of normal thickness for 1932 in these trees.

It is usually difficult to discover any benefits from drought, yet in one instance a 3-month dry spell temporarily reduced brown-spot disease on longleaf seedlings.

Lightning and Wind Damage

Lightning often hits the taller and more isolated trees, exposing the inner bark, cambium, and sapwood in a long scar. The wounds attract bark beetles and harbor decay, and may well result in early death from windfall. On the Choctawhatchee National Forest, the loss of longleaf seed trees from lightning was reported at 0.5 percent in 1930 (Pl. 37).

Strong winds may break trees but rarely uproot large longleaf pines, which have relatively stout and deep taproots.²² Uprooting of the smaller trees by wind usually occurs in winter or spring after excessive rain, when the soil is softened by saturation and the anchorage of the roots is weakened. Breakage is most likely in butt sections weakened by turpentine.

Damage to virgin longleaf pine forests from windstorms has been most serious in a belt about 50 miles wide near the Gulf Coast. In the hurricane of September 1906 landowners in southeastern Mississippi suffered enormous timber losses from windthrow. From 30 to 90 percent of the merchantable timber was blown down over an area about 50 miles wide and 150 miles long (157). The owners in this case had 6 or 7 months in which to salvage the fallen trees, and probably 30 percent were utilized. Another destructive windstorm occurred in the fall of 1909 in Louisiana. Fortunately, hurricanes usually occur in the fall, when insects and fungi are not active.

Many storm-felled trees were salvaged after the hurricane of September 1928 in Florida. A large proportion of the standing trees suffered internal injury. A defect called "wind-shake" extended from turpentine faces upward to various distances in the stem. Turpentine borers frequently gained access through the small breaks caused by the storm.

²²Records kept over a 5-year period (98) for 240 acres of pure longleaf pine forest showed tree mortality as follows: from wind, beetles, and lightning, 90 percent; fire, 9 percent; and rot, 1 percent. Wind accounted for 44 percent of the board-foot volume lost. While only 1 percent of the tree mortality in this instance was attributed to rot, the volume of wood lost from decay was much greater.

Wind damage to second-growth forests is slight except where severe storms have struck. Tornadoes, which are more likely to damage forests in the northern than in the southern part of the longleaf belt, affect a smaller area of forest than do hurricanes. Along its swerving and erratic course, however, a tornado leaves swaths of leaning, broken, and uprooted trees.

In thinning and improvement cutting, the elimination of leaning trees is desirable because many contain or develop compression wood which is brittle, shrinks excessively longitudinally, causes warping, and does not even make satisfactory pulp. Removal of such trees will not only reduce losses from wind, but will strengthen sound trees that may later be reserved for seed production.

Hail, Ice, and Snow Damage

Hail storms sometimes cause minor damage to longleaf pine through defoliation and bruising of the bark. Following such injury, the trees may be attacked by engraver beetles or other insects. On April 30, 1937, on the Kisatchie National Forest, hailstones intermittently cut through the bark of stems as large as five inches in diameter, the wounds being visible four years later (541). Some saplings were retarded in growth until 1939. A thin band of summerwood formed a distinctive ring in 1937.

The formation of ice on trees is not common in the longleaf belt. When it happens the weaker trees are broken or bent, while tops and limbs are torn from the stronger trees. Longleaf pine, in spite of its sturdiness, is vulnerable to ice because the long needles gather too much weight for the branches to support.

Sleet or glaze storms may bend seedlings and young trees up to about 6 inches in diameter. A sleet and snow storm struck northern Louisiana on January 14, 1944, and 3 weeks later about 90 percent of the longleaf pine saplings 10 to 24 feet high and 1 to 4 inches in diameter were still bent over from the ice. Some 3½ months after the storm, however, 90 percent of the bent trees had straightened.

The same storm caused more damage to a stand of longleaf pine saplings 50 feet high and 30 years old that had been released only 2 years earlier by cutting pulpwood to a 5-inch diameter limit. Half the trees in the stand were severely, and perhaps permanently, bent over. This indicates that excessive delay in thinning dense thickets of young pine tends to increase the number of potential crop trees susceptible to damage from snow or glaze as soon as they are released. Partial cuttings should aim to leave only straight, sturdy trees.²³

SUMMARY

Longleaf pine forests have had nearly 100 years of freedom from widespread insect scourges. During its brief cotyledon stage, this species shows no special

²³Because of their thinner and more flexible branches, the other southern pines may be expected to shed a greater portion of wet snow before it freezes, but there is no evidence that slash pine has so benefited, perhaps because of slender stems and heavy foliage. Damage from the 1944 storm in Texas was heavier on loblolly than on longleaf pine.

An ice storm of January 7, 1940, injured longleaf and slash pines in plantations near Athens, Ga. (366). The final net loss resulting from breakage, uprooting, and bending beyond recovery was 24 percent for longleaf, 29 percent for slash, and 4 percent for loblolly pine.

immunity, being susceptible to fatal injury by ants and the larvae of May beetles, sawflies, and cutworms. West of the Mississippi River, a leaf-cutting ant sometimes causes serious depredations during the grass stage and requires chemical control. Pitchmoths sometimes infest shoots, flowers, and cones, interfering with seed production. Among the bark beetles, *Dendroctonus* is potentially dangerous but has done little damage in recent years. *Ips* frequently take extensive toll among the weaker trees, particularly during periods of severe or protracted drought. The round- and flatheaded wood borers, termites, and other insects infest dead and down timber only. Conservative chipping of turpentine faces and protecting them from scorching will minimize damage from the turpentine borer, a relatively serious pest. Normally, insect infestations are spotty and small, because longleaf pine repulses many attacks promptly with a profuse flow of gum. Many outbreaks of bark beetles follow forest fire or cutting, and can largely be avoided through control of these factors.

Brown-spot needle disease is serious mainly on seedlings of longleaf pine, causing severe defoliation. Heavily diseased stands are common on unburned areas, resulting from multiple infections spread by splashing rain. Fungicidal sprays provide effective control in nurseries, and easily restore normal rates of seedling development in the field if the cost can be justified. Spraying in May and November of the first two years usually results in satisfactory control. Where the infected seedlings are established but not yet above the grass, controlled winter burning is recommended at intervals of about three years until a sufficient number start height growth.

Species of a native fungus, *Cronartium*, cause minor difficulty by infecting cones and producing rust cankers on stems. Various associated oaks are alternate hosts for some of these pathogens. Longleaf pine is much more resistant to stem canker than are the other southern pines. Heart rots, extensive in virgin timber, are not serious in second-growth stands. Cutting provides the only control, improvement cuttings and thinnings being usually sufficient.

Protection of the forest against animals can be effected by proper fencing where numerous hogs have free range in seedling stands. Razorback hogs are outstanding enemies of longleaf seedlings, and must be excluded from regenerating lands. Seedlings are often injured also by sheep and goats, and their exclusion is likewise desirable, but cattle do little damage except to yearling pines, and on lands that are heavily overgrazed. A 2-year exclusion of fire from reseeded lands protects the seedlings not only from fire injury during their defenseless cotyledon stage, but also from injury by cattle. Livestock tend to concentrate in the more open woods and on freshly burned areas.

Several species of birds—principally meadowlarks, doves, quail, cowbirds, and various blackbirds—eat longleaf pine seeds, sometimes consuming the whole crop at seed fall. Sapsuckers occasionally attack the trunks of trees, causing some degrade in the lumber. Rodents also consume pine seed when available, but studies in southern Mississippi have indicated that rodents are not numerous on longleaf pine lands. In this region, it is estimated that birds eat the most seed, followed by hogs, rodents, and ants in the same order.

Although climate is normally favorable to southern pines, drought frequently kills the weaker trees, including those damaged by severe turpentine and fires. Lightning damage is most conspicuous on the larger, more valuable trees. Ice storms, prevalent along the northern boundaries of the longleaf range, cause widespread damage to saplings and poles, especially when accompanied by high winds. Severe winds preceded by soil-saturating rains may uproot some trees and leave many permanently tilted. In turpentine orchards, where deep incisions are made for the insertion of gutters, many trees are split open or broken off by high winds. Climatic injury is often followed by injury from fire, decay, and insects. Damage from insects or disease combined with climatic injuries frequently causes mortality, but this can be minimized by improvement cuttings and thinnings.

Part 5. MANAGEMENT

X. Naval Stores Operations

THE United States is the world's leading producer of naval stores. All of its production comes from two species, longleaf and slash pine.¹

ORIGIN AND EXTRACTION OF GUM

The principal liquid that exudes from a wounded pine tree is oleoresin, commercially called gum. The source of oleoresin production is still much debated. The resin passages are intercellular spaces formed, apparently, by the drawing away from each other of the thin walls of neighboring clusters of parenchyma cells exuding resin. The resin passages, or ducts, which are an outstanding characteristic of all pine wood, reach a notable development in slash and longleaf pines. Many are visible in magnified cross sections. In tangential sections of longleaf, a square inch of sapwood surface contains 300 to 400 rays having resin ducts. The ducts extend both vertically and horizontally, forming two interconnecting systems throughout the woody stem. Severance of the vertical resin ducts permits the gum in the radial ducts to be drained, or vice versa.

The initial flow of gum from ducts in normal wood (not stimulated by wounding) is supplemented later by gum from the subsequently formed traumatic tissue (wood modified as a result of wounding) where the resin ducts in the springwood are more abundant. The vertical ducts may be increased as much as tenfold, especially in the new wood laid down 2 to 3 feet above the point where chipping begins each year (Pl. 38). The wound must be kept fresh by repeated chipping; otherwise the flow of oleoresin will cease and the severed parenchyma cells will become dry and clogged with hardened gum, and will die.

That the relative abundance of resin ducts formed after wounding a tree is a significant factor in increasing gum yields is indicated by a simple test. Wood formed above the face since turpentineing began is separated from older wood by a metal shield diverting the gum to a separate container. The new wood exudes nearly twice as much gum per square inch as did the inner wood formed before chipping commenced (79).²

Oleoresin has two forms, "dip" and "scrape." Dip is the portion caught in a cup hung on the tree; scrape is gum that hardens on the face of the tree and has to be scraped off when collected. Both are distilled to produce spirits of turpentine and rosin, the principal products of the naval stores industry.

¹All pines are resinous but few produce gum in commercial quantities. In Europe the chief producer is maritime pine (*Pinus pinaster*), grown mainly in southwestern France. Scotch pine (*P. sylvestris*) is worked in Russia, Germany, and Austria; Austrian pine (*P. laricio*) in Austria and the Balkan states; and Aleppo pine (*P. halepensis*) to a small extent in Mediterranean countries. In India, naval stores are obtained from chir pine (*P. longifolia*). Little is known of the wartime status of the industry in the Far East, but probably Benquet pine (*P. insularis*) is producing in the Philippines, and Tinyu pine (*P. merkusii*) in the East Indies. In northern countries short growing seasons and low yields make large-scale naval stores operations unprofitable.

²The test does not show the comparative yield from outer rings of wood that formed next to the bark before the first wounds were made.

Scrape yields about 10 percent turpentine, dip about 20 percent. Roughly 40 pounds of dip or 80 pounds of scrape produce a gallon of turpentine. Scrape, however, produces more rosin than does dip, although it is of a lower quality.

Pines less than 9 inches in diameter should not be turpented, and no tree under 14 inches should be worked with 2 faces simultaneously.³ This is the currently accepted practice. Chipping, which consists of removing a strip of bark and sapwood about a half inch deep, starts with 2 diagonal streaks about a foot above ground. Succeeding streaks remove strips just above the last cuts. This repeated chipping with a sharp tool, called a hack, keeps the wound fresh and causes the gum to flow continuously. Trees are chipped weekly in summer, at shorter intervals in the warmest weather and longer ones in cool temperatures. In winter the trees are usually not turpented, but should be chipped every 2 to 4 weeks, if worked at all.

As chipping advances up a tree it leaves a face of exposed wood over which the gum must flow to reach the cup. This cup together with the apron or gutter—the tins used to guide gum into the cup—should be raised annually with the face. When chipping is resumed on trees not worked in winter, a strip of bark may be left uncut to avoid wood clogged with resin. The next streak is then called a jump streak.

Cycle of Turpentineing

After being worked for 5 or 6 years (depending on the height of the streaks) and reaching a height of 6 feet or more above ground, trees should be rested for a year or more before resumption of turpentineing—that is, back facing. Most trees can be back faced for 5 or 6 years. Some trees with wide bark bars can be worked still longer if allowed to rest for about four years after back facing. During this rest period the trees enlarge their bark bars and gain in thrift, thus permitting a third period of turpentineing. By the time the second period starts, many of the smaller round trees in the stand have reached 9 inches in diameter. Thus, in many stands front faces are being chipped on smaller trees simultaneously with back faces on the larger trees and third faces on the largest trees.

It is biologically possible to extract gum from a tree until its face dries or the tree dies, but actually most trees are actively worked only 10 to 12 years before they are discarded or used for other purposes. A stand of trees, however, may serve as a turpentine orchard for 20 years or longer depending on the number and growth rate of recruits—small round trees—that grow up to turpentine size.

Gum from the chipped faces may be lost from many causes—evaporation, running to the ground instead of to the cup, dry facing from drought, uncontrolled fire, etc. All these conditions usually can be corrected by proper supervision.

In virgin stands turpentineing always preceded lumbering by 3 years or more. Second-growth stands are now worked much longer than 3 years. With the exception of trees reserved for special purposes (export timbers, etc.), turpentineing generally is the prelude to harvest cutting. Trees worked out for turpentine should be removed from the land at the earliest opportunity. Worked-out trees are fortu-

³Turpentineing that can qualify for Federal subsidy is specified in a leaflet, 1944 Naval Stores Conservation Program Bulletin, issued November 4, 1943, by the War Food Administration, Agricultural Adjustment Agency, U. S. Department of Agriculture.

nately no longer a drug on the market, as formerly, except in districts remote from sawmills or pulp mills. They yield sawlogs or pulpwood except for the turpented butt,⁴ and should be removed to make room for reproduction or advance growth.

COMPARISON OF LONGLEAF AND SLASH PINE

Longleaf pine reaches turpentine size later than slash. On medium-quality sites, where slash grows 1 inch in diameter in 5 years, longleaf requires 7 years. The increase in turpentine yields with each additional inch of diameter growth is nearly six units⁵ per crop (10,000 faces) for slash and about four units for longleaf. Turpentine yields from 6-inch slash and longleaf trees are nearly alike, but for larger trees the slash pine proves to be a better naval stores tree (630).

Cary (79, Inst. 2) noted that slash pine stands yield 25 percent more gum than longleaf. Liefeld, in a study of yields from bark bars on previously turpented trees, found that slash pine averaged about 35 percent more gum than longleaf during the first year and approximately 15 percent more in the second year (341).

The rapid loss of certain volatile ingredients of longleaf pine gum has been noted. Wyman (629) called attention to the direct and only partly preventable evaporation losses, and Cary (79) observed that the loss in yield from neglecting to raise tins was only about half as great for slash as for longleaf pine. Harper (254) noted that the proportion of scrape in the total yield is 15 to 20 percent greater in longleaf than in slash pine. Hence it is not surprising that oleoresin from longleaf has a smaller turpentine content (573). Otte⁶ failed to confirm this observation, but found that for the same degree of purity in crude gum, the rosin from longleaf is darker and therefore of lower grade.

Two other minor physical differences may be mentioned. Hawley and Wise (269) indicated that oil of turpentine from longleaf pine is normally dextrorotatory while that from slash pine is levorotatory. This was later measured by Black and Thronson (40); the two-season average for longleaf turpentine was $+11.31^{\circ}$ and for slash turpentine -19.32° . Turpentine obtained from slash pine oleoresin was of slightly lower specific gravity than that from longleaf.

Young thrifty longleaf trees are less easily injured than slash pine by working for turpentine. Not only can full-topped, open stands of longleaf be chipped deeper without undue injury, but longleaf also suffers less from dry facing. In one instance, when turpentering was resumed after the faces had been scorched by fire, slash showed 6 percent more dry face than longleaf (414). Austin Cary (79) found evidence that slash was more severely affected than longleaf by heavy cupping, the difference being manifest in retarded growth, lower gum yield, and higher mortality. Forest Service surveys have shown that mortality from very severe turpentering amounts to 28 percent in slash but only 20 percent in longleaf.

⁴The turpented butt is too pitchy (and sometimes too blackened with charcoal) to be sold for most purposes. It may be cleaned up, however, and used as pulpwood or poles. Many butts are used as fuel, either at turpentine stills or elsewhere.

⁵A naval stores unit is one 50-gallon barrel of turpentine and 3-1/3 500-pound (gross) barrels of rosin.

⁶Otte, B. J. H. A study of the composition of the oleoresin of *Pinus palustris* and *Pinus heterophylla* from high, medium, and low yielding trees. 1930. Master's thesis. University of Florida. [Unpublished.]

BOXES AND FRENCH FACES

The earliest receptacle for collecting gum was a hole dug at the base of a tree. This crude custom was soon abandoned and a cavity or "box" 4 inches wide and 4 inches deep was hewn in the butt, a procedure which was obviously wasteful (276, 461, 481). These boxes so weakened the trees as to cause a loss of 5 to 10 percent of the stand every 4 years. Gum fires in boxes were particularly injurious. Boxes continued to be widely used until about the time of World War I, when the modern cup-and-gutter system was extensively adopted. Three cups can be hung in the time needed to chop one box, and, with the exception of the first "dip" or collection of gum, all yields are higher with cups (278).

The practice of cupping resulted in a new abuse, however, since trees too small for boxing could be easily cupped. Despite the fact that work on such trees was not remunerative, and that aggregate increases in output depressed prices, the chipping of trees as small as 5 or 6 inches in diameter continued for many years.

Relatively narrow French faces (Pl. 39), which are better adapted than American faces to small second-growth trees, have been tested on the national forests. Because of working more trees per acre and more faces per tree, the over-all production per acre was greater. Harper (255) found that on young longleaf pine 5-inch French faces yielded 22 percent more gum the first year than 5-inch American faces, and 16 percent more the second year. Liefeld (342) also compared French and American faces on longleaf pine over a two-year period. For both kinds of faces chipping was one-half by one-half inch, but the French faces had the advantage of about four inches of wood freshened on the old face by each streak. French faces yielded 20 percent more gum for the first year of work than American faces of the same width (Fig. 49). During the second year, however, American faces yielded slightly more gum than French faces (Table 44).

French faces can be worked longer than American faces and heal more quickly (365). Towards the middle of the 1920's an improved tool was devised for making two French faces in the time required to chip one American face (626). French faces have not been adopted in the United States, however, because they do not have enough advantages to compensate for the difficulty in teaching an entirely different chipping method to Negro turpentine workers.

CHIPPING

Much experimental effort has gone into the study of the height, depth, and length of streaks, which together with their number, determine respectively the height, depth, and width of turpentine faces. Whatever the dimensions, chipping should be done with a small, very sharp hack. Working with a dull hack may cause a 15-percent loss in gum yield (432).

Streak Dimensions

Chipping low streaks twice a week in the height of the producing season increases total yields. Low chipping, however, probably influences this result less than stepped-up frequency. For a given frequency of chipping, high streaks are wasteful

LONGLEAF PINE

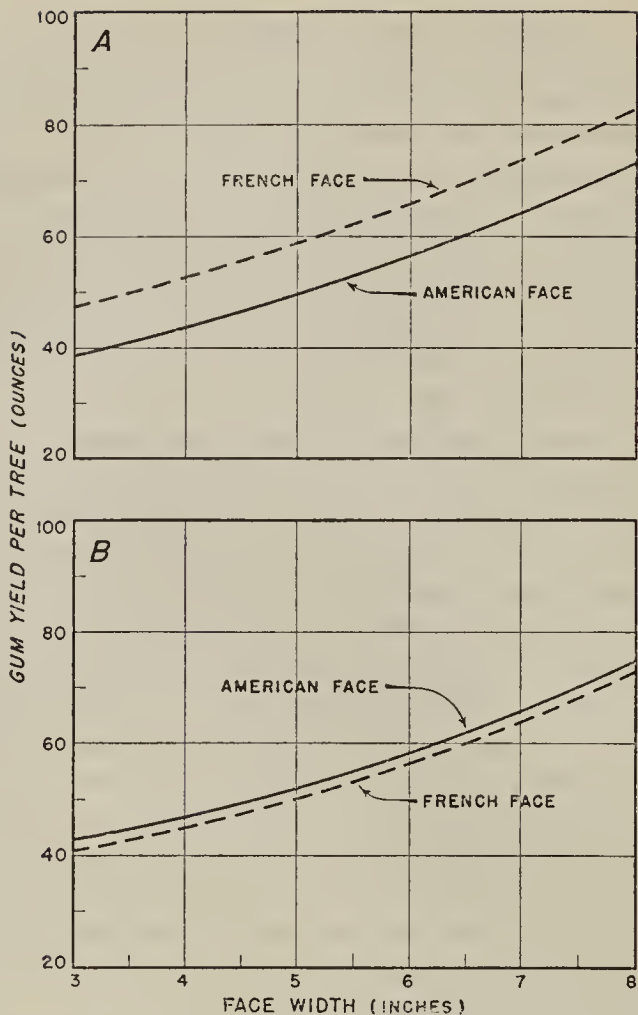


Figure 49.—Yields of longleaf pine gum from French and American faces chipped on 12-inch bark bars (9-inch trees). A, first-year work; B, second-year work. (After Liefeld)

Table 44.—Average first- and second-year yields in barrels of turpentine per crop from faces of different widths on bark bars of longleaf pine, by style of face, diameter of tree, and width of bark bar¹ (342)

Width of face (inches)	First year						Second year					
	French face			American face			French face			American face		
	Tree diameter ² (inches)						Tree diameter ² (inches)					
	6	10	14	6	10	14	6	10	14	6	10	14
	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>	<i>Bbls.</i>
10-INCH BARK BAR												
4	10	18	27	7	16	24	4	15	25	5	15	25
6	15	23	31	12	20	28	10	20	30	10	20	31
8	20	28	36	17	25	33	14	25	35	15	25	36
14-INCH BARK BAR												
4	12	21	29	10	18	26	7	17	27	7	18	28
6	17	25	33	14	22	30	12	22	32	12	23	33
8	22	30	38	19	27	36	17	27	37	17	28	38
18-INCH BARK BAR												
4	15	23	31	12	20	28	9	19	29	9	20	30
6	19	27	36	16	24	33	14	24	35	15	25	35
8	24	32	41	21	30	38	19	29	40	20	30	40

¹Each year 32 streaks were used. The yields shown above are for bark bars growing at the rate (7 rings per inch) that produced maximum yields for the growth rates represented in the experiment. A crop = 10,000 faces. A barrel = 50 gallons.

²At 10 feet above ground.

Table 45.—Yields of turpentine and rosin per crop, from longleaf pine, in relation to height and depth of streak¹ (After Wyman)

Streak (inch)	Turpentine ²					Rosin				
	1924 <i>Bbls.</i>	1925 <i>Bbls.</i>	1926 <i>Bbls.</i>	1927 <i>Bbls.</i>	Average <i>Bbls.</i>	1924 <i>Bbls.</i>	1925 <i>Bbls.</i>	1926 <i>Bbls.</i>	1927 <i>Bbls.</i>	Average <i>Bbls.</i>
YIELD IN RELATION TO HEIGHT OF STREAK										
0.32 -----	32.4	30.5	33.8	19.9	29.2	113.9	104.0	112.3	78.0	102.0
.5 -----	42.8	46.4	40.2	32.2	40.4	141.8	147.9	135.6	116.7	135.5
.73 -----	43.7	41.0	34.7	29.0	37.1	149.8	132.4	114.6	105.0	125.4
YIELD IN RELATION TO DEPTH OF STREAK										
0.3 -----	34.8	44.0	32.9	27.8	34.9	111.7	135.1	103.9	100.1	112.7
.5 -----	42.8	46.4	40.2	32.2	40.4	141.8	147.9	135.6	116.7	135.5
.75 -----	34.9	46.2	33.1	29.2	35.8	117.0	144.3	108.0	107.1	119.1
1.0 -----	38.9	38.5	30.6	27.0	33.8	125.6	120.8	99.9	99.8	111.5

¹Timber 9 to 14 inches in diameter and about 25 years old. Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net.

²Bureau of Chemistry and Soils converting factors for turpentine yields used as follows: For 0.32-inch chipping, 22.3 percent weight of dip and 10.2 percent weight of scrape; 0.3-inch chipping, 23.4 percent weight of dip and 11.5 percent weight of scrape; 0.5-inch chipping, 22.9 percent weight of dip and 11.2 percent weight of scrape; 0.73-inch chipping, 22.9 percent weight of dip and 10.9 percent weight of scrape; 0.75-inch chipping, 23.2 percent weight of dip, 11.5 percent weight of scrape; and for 1-inch chipping, 23.2 percent weight of dip, 11.2 percent weight of scrape. For all groups, 7.4 percent of the gum weight is water and trash.

in two ways: (1) they may extend beyond the zone where wound-induced ducts are most abundant, and (2) a rapid advance up the tree brings the peak of the face out of reach too quickly. High third-year faces, worked with a long-handled hack called a "puller," often receive unintentionally low streaks confined to highly productive wood, but the same increased output (nearly double the yield per tree) can be had from low faces, as was demonstrated on the Choctawhatchee National Forest.

Additional advantages from low faces are reduced scar, less lumber degrade, earlier and more abundant wood formation, especially of summerwood, and longer working of the trees (204, 206, 207, 208, 211).⁷ On trees 11 or more inches in diameter, low working permits the chipping of one face for 10 to 12 consecutive years, whereas moderately high-chipped faces are worked out in 7 years and high-chipped faces in 5 years. This additional working should furnish up to about 40 percent more gum from each face (Fig. 50, A). In one test on longleaf pine covering a period of 4 years, chipping ½ inch high was found to be most successful (Table 45) (630).

The most desirable length of streaks for each stand cannot be easily determined—longer streaks sever more resin passages, but they do not always increase yields. Long streaks may cause excessive wounding and severe drying at the middle of the face or where the streaks are deepest, leaving only a portion in good productive condition. Narrow faces heal more quickly than wide faces and improve the prospects of satisfactory back cupping. As a rule, faces should not exceed 12 inches in width or one-third the circumference of a tree.

Shallow chipping sacrifices some yield for the first year or two, but thereafter adverse effects like dry facing or windfall, common to deep chipping, are usually

⁷Longleaf pine forms 50 percent more scrape with streaks ¾ inch high than with streaks 1/3 inch high (633). In one test narrow ¼-inch chipping increased the value of first-year yields, while in others no advantage was manifest for the first 2 or 3 years but total yields were 50 percent greater (627).

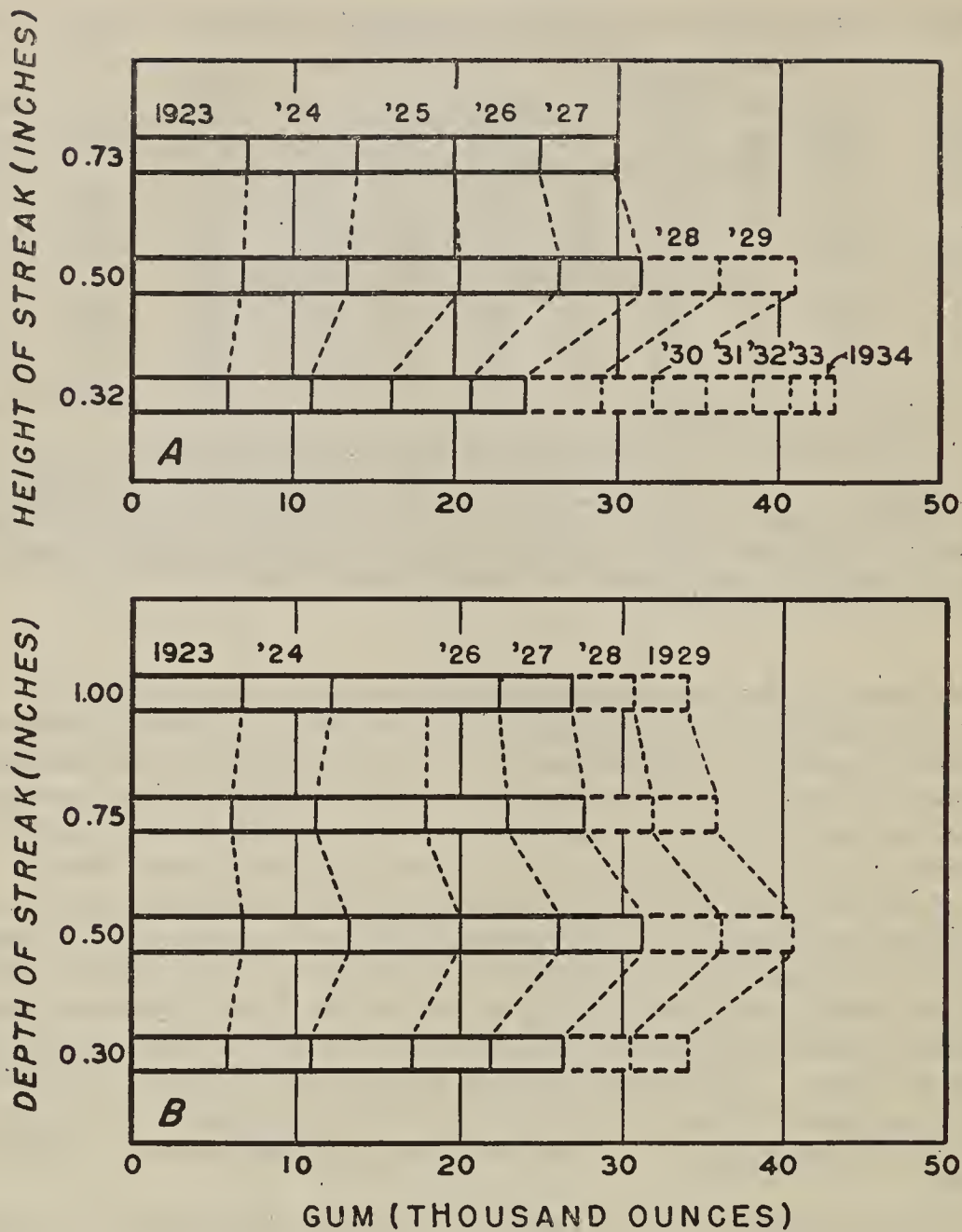


Figure 50.—Cumulative naval stores yields from second-growth longleaf about 25 years old and 9 to 14 inches in diameter. Dotted lines represent estimates of expected yields. (After Wyman)

avoided (617). Very deep chipping is unprofitable except in short-term exploitive turpentineing. Cary (79) observed that $\frac{1}{2}$ -inch streaks yielded $17\frac{1}{2}$ percent less gum than $\frac{3}{4}$ -inch streaks the first year, but over a 3-year period the shallower chipping was more productive. Groups of trees that were chipped deeply ($\frac{3}{4}$ inch and 1 inch) decreased in yield at a rate that made 7 years' work distinctly unprofitable compared with shallow chipping. He concluded that the $\frac{1}{2}$ -inch depth was most productive.

Thus, it is recognized that streaks which are oversize in any or all dimensions eventually reduce yields because they wound the trees severely; delay formation of wood fibers and resin-producing tissue; contract the width of annual rings, summerwood bands, and walls of summerwood cells; and at the same time increase dry face and mortality (205).

Advance Streaking

Advance streaking when hanging cups in winter has become an almost universal practice, since it tends to build up the capacity of the tree to yield gum and thus produce at the highest rate when regular chipping begins in the spring.⁸ The use of advance streaks may increase yields 50 percent for the first 2 or 3 streaks chipped, the rise diminishing to 2 to 5 percent by the ninth streak, averaging perhaps 3 percent for the whole season (345). By far the greatest value is realized early in the season, when the price of gum is usually higher than it is later in the season.

Streak Intervals

Intervals between chipping have an important influence on naval stores yield.

Where no chipping is done in winter and high winds are uncommon, jump streaks are sometimes used. They provide a quick and cheap way of avoiding the gum-clogged lightwood which, in the absence of winter work, forms during the rest period. There are both advantages and disadvantages in jumping. It wastes wood, labor, and gum if the lightwood is only about a half inch high; the first dipping takes too long; cuts are too deep; and the gutters (used instead of aprons) fail to guide all the gum into the cup. If tins are raised too close to the jump, chippers, striving to get above the tins quickly, may waste wood by chipping the first five or six streaks too high; they may also reduce the yield by narrowing the face. If tins are not elevated above their first position, the scrape tends to pile up slightly on the faces, creating not only a fire hazard but, in coastal areas, a loss of gum that drips and blows away.

On the other hand, if certain precautions are taken and light winds prevail, jump streaks are economical, especially if tins are elevated just below the jump, or the bark is removed from the jump to decrease the ledge. Some operators substitute jump streaks for the raising of tins in alternate years, and avoid the leakage of gum around and behind the tins. With jump streaks and elevated tins, the proportion of scrape may be cut nearly in half (Pl. 40, B).⁹ Jump streaks seem to speed the passage of gum by causing it to drip directly onto the tins without running over the lower part of the face. Evaporation losses are reduced and rosin grades are better than when the gum slowly traverses long faces to reach the cup.

Chipping costs are the same whether jump streaks are used or not, except when pitch soaking of wood occurs in winter. Then the jump streak is the more econom-

⁸The stimulating effect of advance streaking was discovered when it became apparent, in the days when boxes were used, that the wounding of trees in making boxes increased the flow of gum. In the deep South advance streaks are usually cut in December, giving the trees more time to respond before summer chipping starts. In northerly sections, such as the Carolinas, frozen sapwood may require a jump streak of 6 inches or more to regain productivity. Hence, operators may begin preparatory work later than in the Gulf Coast region.

⁹A test with longleaf pine showed 28.3 percent scrape without and 16.9 percent with a jump streak.

ical because no extra chipping is needed to start the flow (631). In short, jump streaks applied to inland crops of turpentine usually reduce not only the cost of handling tins but also the wastage of gum.

Longleaf pine should be chipped about every other week in spring and fall, and once every three weeks in winter, if winter work is done, and weekly in summer (346).¹⁰

In an exhaustive study of gum yields in relation to frequency of chipping, Liefeld found that more than 32 streaks per year did not drain the vitality of the turpented timber excessively (Fig. 51, B). He recommended semiweekly chipping in summer, weekly in spring and fall, and semimonthly in winter where the long working life of the same faces or trees is more important than high gum production per year. Even the most conservative operation would involve chipping not less frequently than every 2 weeks in summer and every 6 to 8 weeks in winter.

For sustained profits, stands should be handled in the conservative way recommended by Liefeld. More frequent chipping, however, is advantageous when rapid utilization and high annual or seasonal production are desired. In no case should a tree be chipped more than three times a week in summer and once every two weeks in winter (346). Although it does not pay to work the smallest and weakest trees, other undesirable trees may well be turpented until exhausted.

Dry Facing

A familiar problem in the turpentine woods is the partial or complete cessation of gum flow from certain trees within a few weeks or months after chipping begins (Pl. 41, A). This dry facing cannot be ascribed to any single factor.

In one investigation, twelve experienced operators were asked their opinions of the causes of dry facing. The consensus of their reports was that dry facing is due to (1) heavy work, particularly deep chipping, (2) drought and dry soil, (3) injury from summer fire, insects, etc., (4) injury from close cupping (too many faces per tree), (5) working trees of too small diameter or with very small tops, and (6) general lack of thrift in the tree.¹¹

Cold weather prolonged enough to freeze the sapwood may cause dry facing. Even flooding may bring it on. Apparently any agency that upsets the normal physiological balance within the tree may induce this phenomenon. To prevent excessive dry facing and mortality it is best to avoid cupping old-growth trees with dead tops or thin sapwood; second-growth trees crowded on all sides, with poor tops, thin foliage, and little taper; and trees under 9 inches in diameter. Two-faced trees should be at least 14 inches d.b.h. Slash pine is generally less resistant to dry facing than is longleaf.

¹⁰For slash pine add 1 week to these intervals because this species flows longer. In one study, longleaf pines required 23 streaks in 31 months, slash only 17.

¹¹Turpentine cuts made sharply across the grain may crush and block resin ducts, whereas heavily slanting cuts seem to leave an angular peak poorly supplied with moisture (79). Hence a moderate angle of chipping helps to avoid dry face. Dry face is less likely to develop under the heavy side of a tree crown than under the opposite side (623).

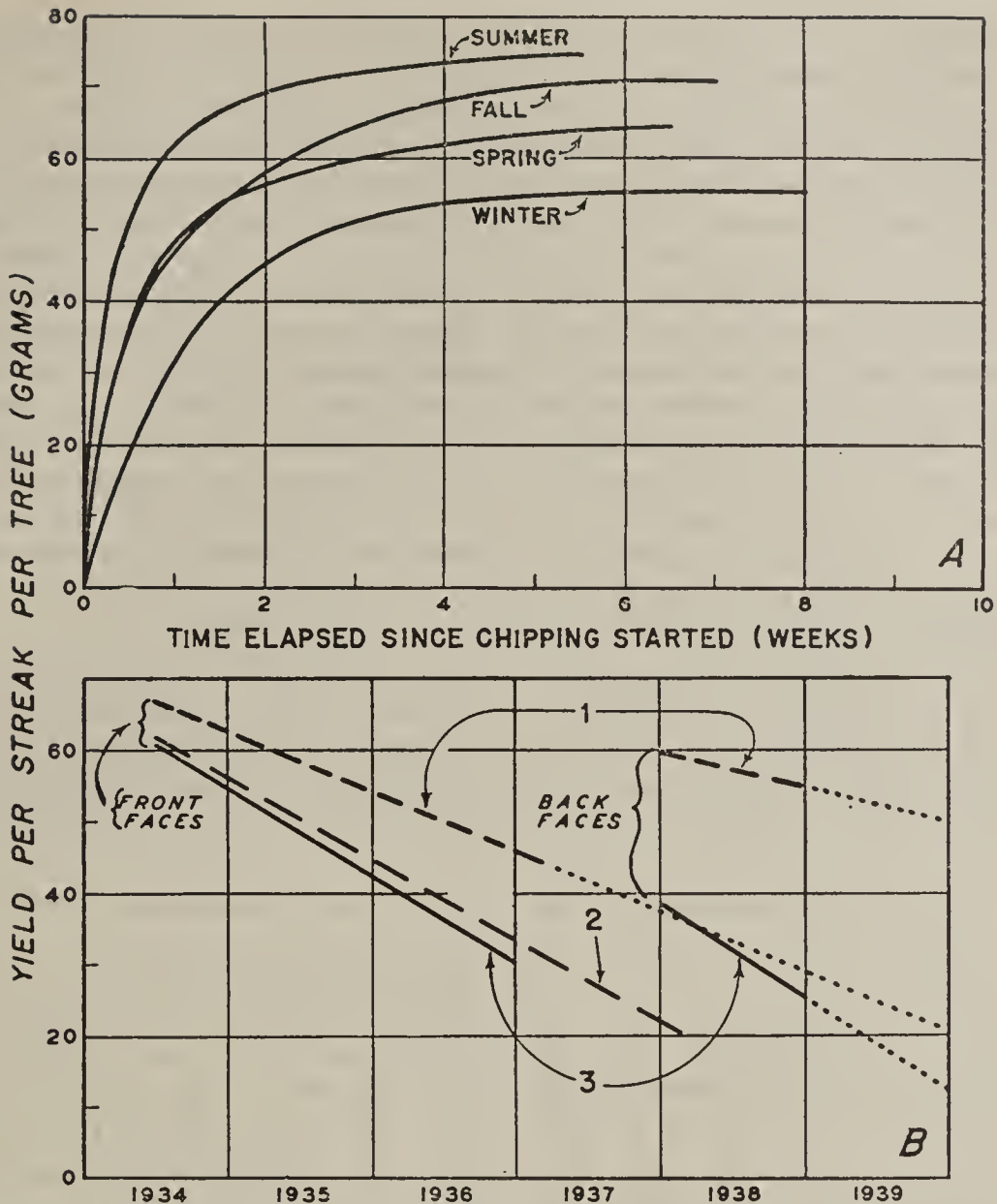


Figure 51.—*A*, accumulated gum yield of longleaf pine for streaks chipped at different seasons and allowed to run dry. *B*, first 24-hour gum yields following chipping under the following treatments: (1) customary seasonal practice of 32 streaks chipped at weekly intervals from March to November; (2) moderate year-round practice of 46 streaks chipped at varying intervals according to season; and (3) heavy year-round practice, 68 streaks chipped at varying intervals according to season (346).

EFFECTS OF WEATHER ON TURPENTINE OPERATIONS

The season of the year has a direct bearing on the selection of chipping intervals because weather greatly influences gum flow (Fig. 52). Harper and Wyman (260), after detailed study of the effects of weather, said:

“When average gum yields for the first, second, fourth, and seventh days after chipping were plotted by months, it was found that first-day yield varied very strikingly from month to month both in quantity and in ratio to subsequent days’ yield.

In winter, the first-day yield was a little less than twice the yield of the second day. The average first-day yield gradually increased from the beginning of the calendar year until midsummer and then declined, reaching approximately its original volume at the end of the year. Average yields for the second, fourth, and seventh days after chipping varied from month to month much less than average first-day yield. . . . Air temperature was more closely associated than any other weather factor with variation in first-day gum yield. Integrated averages of air temperature for the 24-hour period following chipping gave only a slightly higher correlation with first-day gum yield than maximum air temperature during that period." The average gross correlation coefficient for the seven 1928 longleaf groups is 0.9128 for average temperature, 0.9114 for maximum temperature, and 0.8586 for minimum temperature. "The curve showing net relationship of air temperature to first-day gum yield indicates little or no yield for periods during which temperature averages were less than 45° F. During periods with temperature averages higher than 45° the rate of increase of gum yield was slightly higher for each added degree of air temperature. The range of 24-hour average air temperatures was from 40° to 85° and was associated with a first-day gum-yield range from 0 to 100 gm. per tree."

Gum yield was still rising when the highest average air temperature was recorded in this study. Also, first-day yields increased with a rise in temperature of the soil 24 inches below the surface. After allowing for a slight downward trend in gum-yield capacity during the year, Harper and Wyman found that air and soil temperatures and evaporation accounted for most of the fluctuations in yield shown by

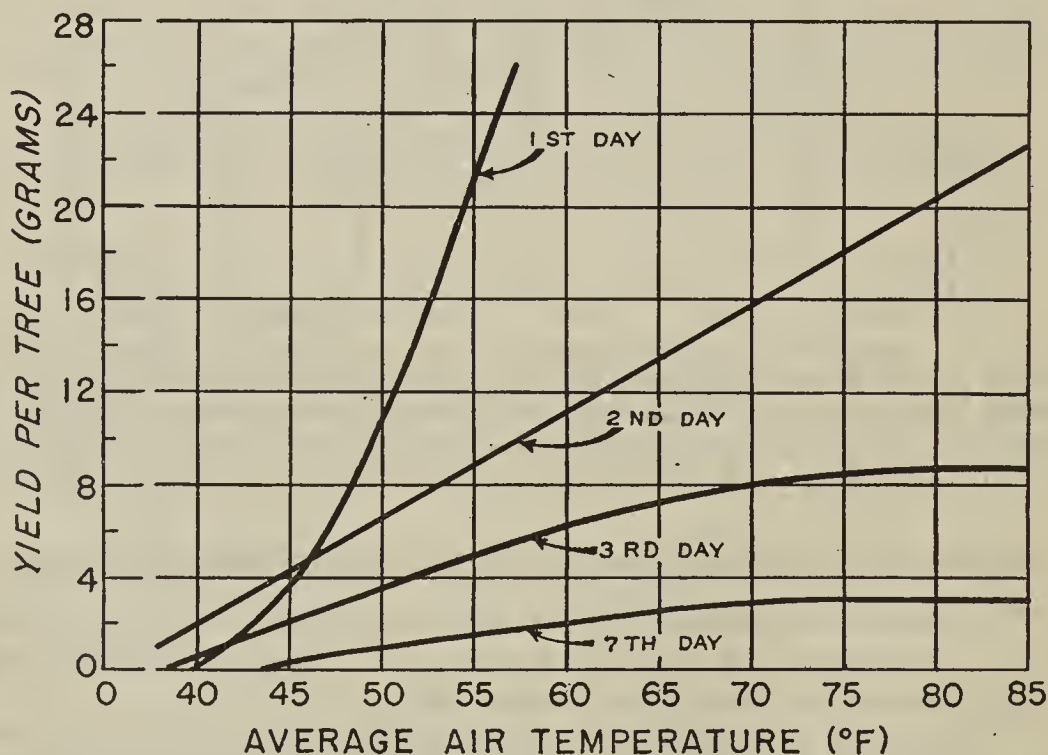


Figure 52.—Effect of temperature on gum yield of longleaf pine by days in the interval between chipping. (After Harper and Wyman)

longleaf pine. Of the three factors, air temperature was by far the most influential in maintaining or decreasing yield. Rain, of course, lowers temperatures, but it had no direct influence on the rate or quantity of gum flow. When air temperatures averaged about 52° F., both slash and longleaf pines required 6 days to yield 90 percent of their weekly total, but at 82° F. this percentage of the weekly yield was obtained from longleaf in the first 48 hours after chipping, and from slash in about 96 hours.

Harper and Wyman arrived at the following conclusions:

"The net effect of weather conditions on gum yield decreased with increase in interval since chipping. The quantity of gum flow on the first day largely controlled the quantity of flow on succeeding days of the chipping interval; a larger than average yield during the first 24 hours after chipping was followed by a smaller than average yield during the latter days of the interval, and vice versa."

EFFECTS OF FIRE ON GUM YIELDS

Working trees for turpentine to some extent alters their capacity for survival, further growth, and gum production if certain types of injury occur. Uncontrolled fires reduce yields in turpentine orchards by lowering the thrift and rate of growth of the trees and by increasing dry face and windfall.¹² In one instance in South Carolina, a 40-year-old stand of longleaf pine suffered a crown fire severe enough to kill or dry face half the trees and reduce the gum flow of the others. One year later the defoliated trees were yielding a normal amount of resin, although wood production was still below normal. In several trees the wood structure above the turpented face disclosed the absence of annual ring for the year after the fire. In trees which had a ring, feeble growth was manifest in poorly developed summerwood and reduced gum-yielding tissue (209, 210, 212).

The destructiveness of fires depends on whether they effectively contact (1) the absorbing root surface that sometimes lies close to the combustible portion of the forest floor, (2) the green needles vital in photosynthesis, (3) the tissue active in the growth of buds and twigs above the lowest branches, and (4) any exposed stem wounds, including turpentine faces (258).

Fire injury to the roots is rare, because humus in most pine soils is insufficient to support a ground fire, while roots imbedded in mineral soil are effectively insulated. Defoliation causes much less injury when needles are killed by heat rising from flames below than when they are consumed by flames in the crowns. Foliage sometimes burns with no apparent injury to stems, twigs, or even buds, but in the most severe crown fires two or more types of injury may be combined.

Defoliation in late spring reduces gum yield about twice as much as in early spring. Complete defoliation is much more destructive than two-thirds defoliation,

¹²Cary (79) found that out of ten 9-inch longleaf pines completely defoliated by fire, three had died and one had dry faced, but the rest showed 60-percent normal gum production the first year, and nearly complete recuperation the following year. Diameter growth, however, was 40 percent subnormal during the 4 years following the fire.

Total defoliation by winter fires in a Georgia forest caused the death of 30 percent of the trees and dry facing of 10 percent. On the remaining 60 percent, gum yields were cut in half, but they were back to within 4 percent of normal production in the second and third seasons. Trees only one-quarter or one-third defoliated showed slight loss of gum production (79).

while the latter is far more debilitating than one-third defoliation. If at least two-thirds of the living crown is defoliated, turpentine should be omitted for a season to permit the tree to recover its vitality.

Fall scraping removes most of the hardened gum from turpentine faces, but usually enough is left to protect the trees from checking and insect attacks. The scraped face is highly combustible, however, and this renders turpentine trees easier victims of fire than round trees of the same size.

After severe spring fires in southern Georgia in 1927, mortality was greatest among turpentine trees because many of the old faces were ignited. Indeed, half of the turpentine trees died, compared with only a third of the round trees.

Following a fire in the autumn of 1931 in Florida it was noted that on the average, 58 percent of the turpentine trees but only 6 percent of the round trees were lost, as follows:¹³

Diameter (Inches)	Round trees (Percent)	Turpentine trees (Percent)
6	7	69
8	3	59
10	11	38
12	0	67
14	0	100
Total	<hr/> 6	<hr/> 58

If trees are scorched but not killed, turpentine may be resumed without using a jump streak, although, if the face is burned, jumping tends to improve the grade of gum collected. The usual jump in such a case averages $2\frac{1}{4}$ inches.¹⁴

Turpentine pines suffer greatest mortality in stands swept by uncontrolled fires. A recent study by Harper (258) classifies fires by intensity (Table 46). He believes that prescribed burning may increase gum yields 4 percent during the first year following fire, owing to a favorable physiological response to increased soil temperature under a surface blackened by fire that does not injure the pines. Crown fires, however, do appreciable damage. Yields of turpentine the first year after burning drop as much as 19 percent as a result of heat-killed foliage, and up to 64 percent from flame-destroyed foliage. Harper concluded that a class-1 fire increases the value of a naval stores lease about 0.25 cent per tree (at wartime prices) for the first year after fire, or 4 to 36 cents per acre, depending on the number of trees turpentine. Although a class-2 fire may have no measurable net effect, the loss from a class-3 fire (involving 1 year of deferment) or a class-4 fire (with loss of faces and trees plus a 2-year deferment) can be serious. With 50 turpentine trees per acre, these losses are estimated by Harper at \$1 per acre for class-3 and \$23 per acre for class-4 fires.

The various conditions in the turpentine forest—with some trees abandoned, some resting, and some still unworked—so complicates the problem of protection that it is difficult to make general recommendations for raking and burning. Usually

¹³Osborne, J. G. Fire damage in the turpentine pine region of the Southeast. 1932. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished.]

¹⁴Study of one fire, however, indicated that a half inch should have been added for each 4 feet of stem scorched (414). On faces to windward, jump streaks may be $\frac{2}{3}$ inch lower than faces in other positions. The least dry face was observed on large, long-crowned longleaf pines with faces to windward.

Table 46.—*Approximate classification and effects of fires that may be encountered in naval stores operations (After Harper)*

Item	Characteristics and effects of fires by intensity classes			
	Class 1	Class 2	Class 3	Class 4
Type of fire—intensity and level	Light surface	Heavy surface	Light crown	Heavy crown
Familiar burning equivalent	Prescribed burning	Light burning	Heavy accidental burning	Conflagration
Avenues of fire injury—vulnerable spots ...	None, or negligible	(1) ¹	(1) or (1) and (2) ¹	(1) and (2) or (1), (2), and (3) ¹
Defoliation ² —individual crowns	0-10%, often none	10-50%	50-100%	100%
Effect on gum yields—first year after fire	4% increase	Nil	25% decline (early fire) 50% decline (late fire)	60% decline

¹Trees are damaged by fire through these avenues of injury: (1) green needles vital in photosynthesis; (2) tissue active in the growth of buds and twigs; and (3) exposed stem wounds, including turpentine faces.

²All the defoliation in classes 1 and 2 is caused by heat only; in class 3, about 40 percent by heat and 60 percent by flame; and in class 4, nearly all by flame.

all working faces should be protected by raking before surface litter is burned. It is also good practice to rake around unburned faces that are resting. The ground around burned worked-out trees should be raked so that additional fire will not weaken and degrade them, especially if they are not to be cut for several years.

NAVAL STORES YIELDS

Yields of naval stores are greatly affected by tree size and methods of working. The output throughout the longleaf pine belt has ranged from 20 to 65 barrels of turpentine per crop (10,000 faces) of virgin growth, and has averaged 35 to 45 barrels per crop for second growth. Under improved management, average yields can be raised to 45 or 50 barrels per crop for second growth and, with the use of chemical stimulants, to 60 or more barrels per crop.

Operators are inclined to work many unprofitable turpentine faces. Hard and fast specifications for selecting trees, however, cannot be formulated because of fluctuating costs of production and market prices for naval stores. As a rule, small and leaning trees do not produce enough gum to pay for working them. Likewise some of the large trees, those that exhibit signs of unthriftiness resulting from rough treatment, severe burning, natural suppression, or previous turpentering may not yield enough to pay for working. In anticipation of the removal of trees unsuited for timber production, however, crooked, knotty, and otherwise inferior trees should be cupped early.

Trees 14 inches or larger in diameter are generally selected for double cupping which, as a rule, does not produce double yields even at the start. Usually only 50 to 60 percent additional gum is obtained at the beginning, with diminishing yields thereafter. If chipping is careless, troubles may follow double cupping. Owing to mechanical weakness, many two-faced trees are broken by wind, and such losses con-

tinue even after turpentine ceases. A sudden increase in the yield of one face is apparent when the extra drain of a second face is removed. It is advisable to avoid a second face on trees less than 14 inches in diameter. In fact, the use of one face at a time, regardless of the size of the tree, is recognized as the best practice except for trees designated for early removal in thinnings.¹⁵

Some trees decline in yield or dry face under heavy working, although this tendency is less pronounced in longleaf than in slash pine. Formerly it was expected that during the first 4 or 5 years of working yields would decline steadily, perhaps as much as 5 barrels of turpentine per crop annually. It is now realized that much of this decline is avoidable through the use of improved methods. For example, Snow (508) found that the simple expedient of tacking gutters in shallow streaks, instead of inserting them in broadax incisions, increased yield 27 percent.

Decline in Successive Years

Successive annual yields on the Choctawhatchee National Forest (where the annual loss from dry facing and death was only 2 percent) were 46, 40, 41, 38, and 41 barrels per crop, respectively. In northeastern Florida, where annual mortality was reduced to 0.3 percent, the year-to-year decline in the yield of second-growth timber did not exceed 1½ barrels of turpentine annually (622, 623).

There is a linear relationship between yield and diameter (622).¹⁶ A comparison of average costs and returns by diameter classes is shown in Figure 53 (225). Assuming a net sale price of \$70 per unit at the still, profits in this instance increased about 3 cents per face for each increase of 1 inch in diameter of the trees worked.

Yield From Back Faces

Prospective yields from back faces depend on the size of the trees and the aggregate width of the bark bars (strips of live wood between faces). The gum yield from a face on a bark bar is somewhat less than that from an initial face of similar width because the first face leaves much more sapwood and bark intact. Factors influencing gum yields from second or third faces are as follows in the order of importance: (1) width of face, (2) diameter of tree, and (3) width of bark bars at the sides of the new faces. The effect of these on first- and second-year yields of turpentine from longleaf pine is shown in Table 47. Note that the yields from 12-inch trees with bark bars 4 inches wide are twice as much for a 9-inch as for a 3-inch face in first-year work, and that in the second year the increase with face width is from 25 to 42 barrels of turpentine per crop. The range in yield with diameter increase is similar. For 9-inch faces and 4-inch bark bars, yields ranged from 30 to 44 barrels the first year and from 30 to 48 barrels the second year as diameter increased from 8 to 14 inches. For 9-inch faces on 12-inch trees, the increase with width of bark bars was from 37 to 43 barrels the first year and from 39 to 46 barrels the second year.

¹⁵In many tests back faces have been found to yield appreciably less gum than front faces on trees of the same size (79). Growth during an extended rest period enables all trees to yield more, but usually trees do not increase in size sufficiently between first and second working without a rest period to avoid decreased yields from back faces.

¹⁶Within reasonable limits the width of face exerts a greater effect on yield than does diameter. Diameter limits face width. Thus the linear relationship between diameter and yield holds only when face width is in proportion to girth (e.g., one-third of the circumference).

Table 47.—Average first- and second-year yields of turpentine¹ per crop from faces of different widths chipped on bark bars of longleaf pine at each side of the face, by diameter of tree and width of bark bars (341)

Width of face (inches)	First year tree diameter (inches) ²				Second year tree diameter (inches) ²			
	8	10	12	14	8	10	12	14
	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels
1-INCH BARK BARS								
3	8	13	18	22	10	16	22	28
5	12	17	22	26	13	19	25	31
7	19	24	29	33	19	25	31	37
9	28	33	37	42	27	33	39	45
2-INCH BARK BARS								
3	9	14	19	23	11	17	23	29
5	13	18	22	27	14	20	26	32
7	20	25	29	34	20	26	32	38
9	28	33	38	43	28	34	40	46
4-INCH BARK BARS								
3	11	16	20	25	13	19	25	31
5	14	19	24	29	16	22	28	34
7	22	26	31	36	22	28	34	40
9	30	35	40	44	30	36	42	48
6-INCH BARK BARS								
3	12	17	22	26	15	21	27	33
5	16	21	26	30	18	24	30	36
7	23	28	32	37	24	30	36	42
9	32	36	41	46	32	38	44	50
8-INCH BARK BARS								
3	14	19	23	28	17	23	29	35
5	18	22	27	32	20	26	32	38
7	25	30	34	39	26	32	38	44
9	33	38	43	47	34	40	46	52

¹Converting factors used to change weight of gum to barrels of turpentine are as follows: turpentine is 20 percent of total weight of clean gum (8 percent of the gum weight is water and trash); 7.245 pounds of turpentine equal 1 gallon; 50 gallons = 1 barrel. 10,000 faces = 1 crop.

²At 10 feet above ground.

Yield by Stand Conditions

Trees in dense stands have restricted crowns and hence a low capacity for gum production. Thus bushy, heavy-topped longleaf pines have been observed to yield 40 percent more gum than do slender forest-grown trees. Second-growth trees yield more naval stores than old-growth trees of the same diameters because they have more foliage. For example, Wyman observed that in second-growth longleaf stands of different densities, the open-grown trees produced 23 percent more gum in 3 years and 31 percent more in 5 years than did close-grown trees (Table 48). Over a 4-year period the yields of turpentine and rosin were found also to be greater from open-grown trees, by 45 to 41 percent, respectively (Table 49). However, the gum yield from trees with crowns of similar size may vary as much as 100 percent owing to inherent or environmental differences.

Rapid-growing, large-crowned, widely spaced trees have other advantages. The decline in gum yields from year to year is less for these trees than for slower-growing, small-crowned trees, and they can be worked profitably over a longer period because the faces heal more rapidly and dry face less, and mortality attributable to turpentine is not so great.

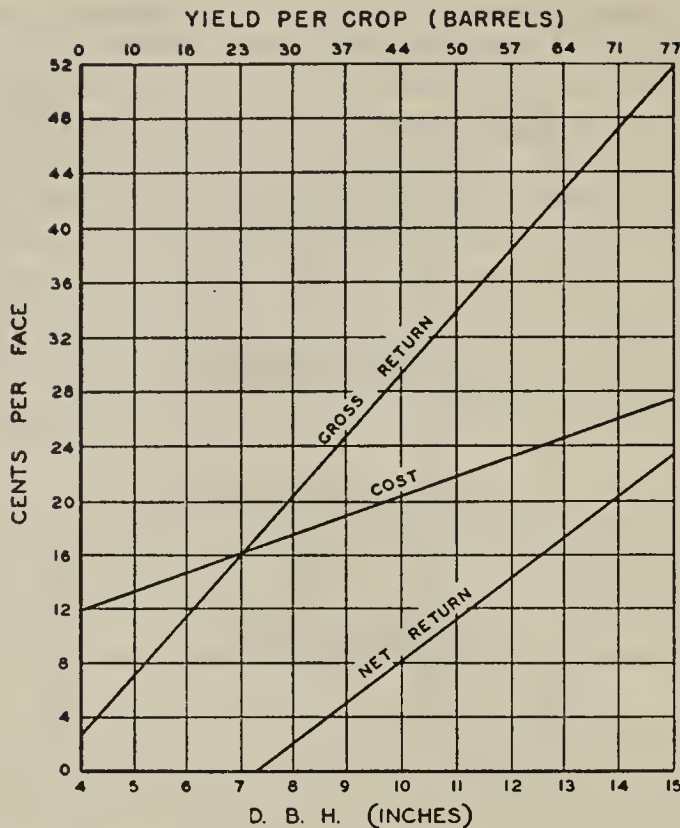


Figure 53.—Cost and returns per face on longleaf pine in relation to tree diameter and yield of turpentine per crop. Based on value of \$70 per unit at the still (225).

Rate of Gum Flow

Just after chipping, gum flows copiously. In the active producing season, i.e., in the spring, summer, and fall, 62 to 80 percent of the total weekly flow occurs on the first day and 87 to 94 percent in the first 3 days after chipping. In winter, the initial flow is much less, about 22 percent the first day and 55 percent in the first 3 days.

The rate of flow varies markedly with the seasons, being much faster in summer and considerably slower in winter than in spring and fall. Gum flow during the first week after chipping in spring and fall is intermediate in amount (Fig. 54), the rates depending on temperature (Fig. 52). After the second week following chipping and until the flow ceases entirely between the fifth and eighth weeks, fall chipping may produce more gum than spring chipping. In these 5 or 6 weeks, the accumulated yields are highest in summer, followed by fall, spring, and winter (Fig. 51, A).

The second year of turpentine often yields about 6 percent more than the first year (Fig. 55, B). Thereafter yields usually decline steadily, particularly under the heavier working schedules in which the interval of chipping is adjusted to gum flow in the various seasons. The most rapid decline is noted from the more heavily worked back faces (Fig. 51, B). Although the rate of flow from a single chipping begins to

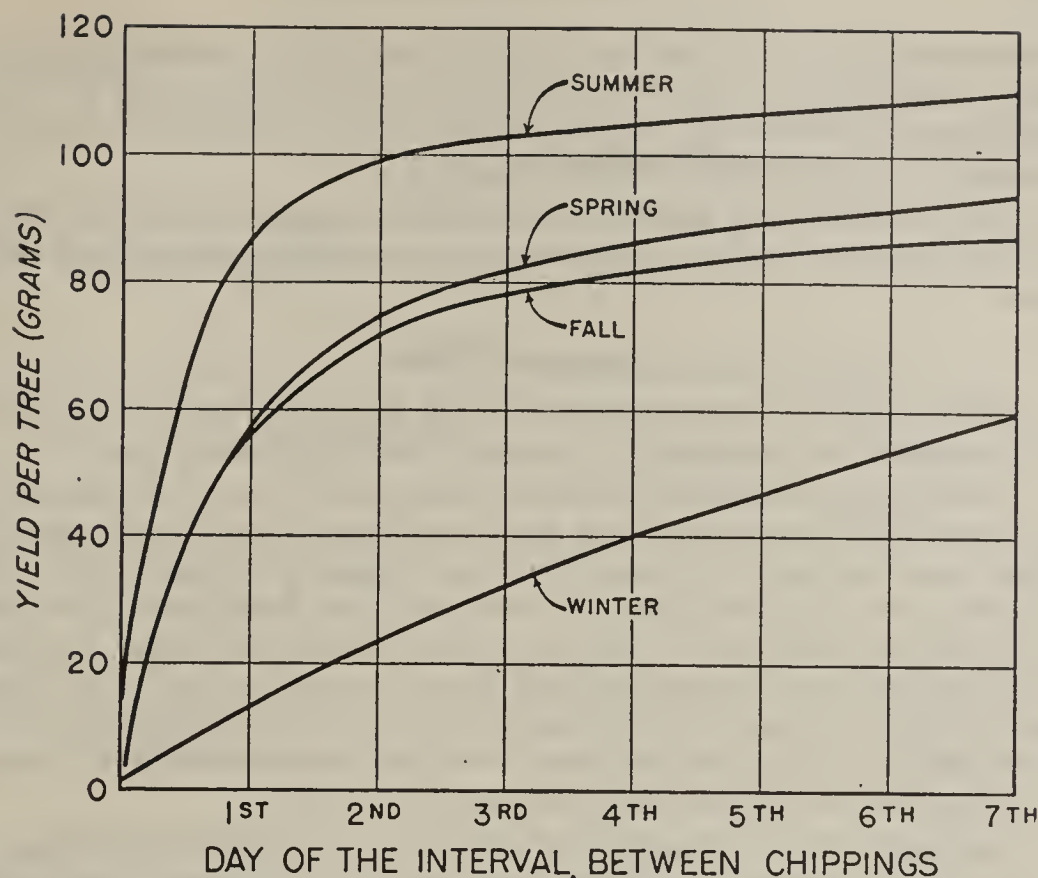


Figure 54.—Effect of season on cumulative gum yields of longleaf pine, by day of interval between chippings. (After Harper)

Table 48.—Gum yields in relation to density of longleaf pine stand, 32 streaks, 50-tree groups (630)

Year	Dense stand ¹	Open stand ²	Increase
	Ounces	Ounces	Percent
1923 ³	6,614	6,905	4
1924	4,693	6,475	38
1925	5,088	6,807	34
3-year total	16,395	20,187	23
1926	3,893	6,170	58
1927	3,779	5,234	39
5-year total	24,067	31,591	31
Decline in yield from 1923 to 1927	2,835	1,671	---

¹135 trees per acre.
²100 trees per acre.
³Computed from measured dip of 22 streaks only, as compared with 32 streaks for other years.

Table 49.—Naval stores yields per crop in relation to density of longleaf stand (622)¹

Year	Turpentine		Rosin	
	Dense stand	Open stand	Dense stand	Open stand
	Barrels	Barrels	Barrels	Barrels
1924	30.5	42.8	103.2	141.8
1925	34.3	46.4	110.7	147.9
1926	25.3	40.2	85.6	135.6
1927	21.6	32.2	85.6	116.7
Average	27.9	40.4	96.3	135.5

¹Turpentine barrel contains 50 gallons; rosin barrel, 420 pounds net. The Bureau of Chemistry and Soils, U. S. Department of Agriculture, converting factors used are dip yields, 22.9 percent turpentine by weight, and scrape, 11.2 percent. Water and trash constitute 7.4 percent of the gum weight.

decrease immediately after chipping, the first-day flow from successive chippings continues to rise during the first year and declines in subsequent years (Fig. 55, A). Beginning in the third year, the gum-yielding capacity of longleaf declines more irregularly than does that of slash pine (Fig. 55, B).

Heavy seed crops may also diminish gum flow. For example, in 1920 a shrinkage of 10 to 15 percent in yields over the entire naval stores region was attributed to this cause.

Quality of Yields

The proportion of turpentine from both dip and scrape can be increased where field conditions favor conservation of the more volatile fractions of the gum.¹⁷

The amount of scrape may be reduced nearly half by using jump streaks and raised tins. Crude gum scraped from the faces of pines is less desirable than that dipped from cups hung on the trees. Gum from longleaf pine contains about 15 to 20 percent more scrape than does gum from slash pine. Small timber yields more scrape than does large timber. Thus, for an 8-inch longleaf pine the ratio of scrape to total yield is about 15 percent higher than that for a 14-inch tree. Also, the proportion of scrape increases with increase in the rate at which a turpentine face progresses upward. A face extended upward 24 inches per year yields about 8 percent more scrape than one extended only 8 inches per year (254).

For longleaf pine the proportion of scrape in gum is appreciably reduced, and rosin grades are improved, if and when the working face is shortened by raising cups (629). In one instance scrape which amounted to 20 percent of the total yield increased to 40 percent when cups were not raised on faces 15 to 20 inches high. Simultaneously, total yields decreased 5 percent or more and turpentine yields decreased 12 to 15 percent.

In slash pine, losses of this kind are only about half as great. Hence, in working longleaf timber the annual raising of tins is clearly profitable (79).

Dark color degrades rosin.¹⁸ The color depends not only on the condition of cups and gutters and on the amount of sand, chips, and other trash in the gum, but also on the tree and species. The rosin from longleaf, being darker than that from

¹⁷The dip and particularly the scrape that arrive at the turpentine still are not the same as the oleo-resin which exudes from wounded pines. Exposed in a thin film on the faces of trees, certain valuable fractions (the more volatile oils) are lost in evaporation, and others are oxidized. Crystallization as well as oxidation of certain resin acids may also occur. While undergoing these changes, longleaf pine gum solidifies into scrape, losing 3 percent of its original weight in the first 3 hours and 8 percent during the first day of exposure. Slash pine gum loses consistently less (629). Gum in the trees is about one-third turpentine, but in barrels often only 18 percent turpentine. Nearly half the turpentine content of crude gum may evaporate before it is barreled.

¹⁸The color of rosin ranges from a very pale yellow through shades of amber and brownish red to nearly black. Since color is an important consideration in some of the industrial uses for rosin, color classes or grades have been established and a letter or abbreviation is used to designate each grade. The palest of the American grades is X, with WW, WG, N, M, K, I, H, G, F, E, D, and B following, the last, B, being an extremely dark brown-red, nearly black. The first three are symbols for the descriptive names, "extra," "water white," and "window glass," which are used in speaking of these grades. Also, in order to avoid possible misunderstanding of the spoken letters, especially M and N, names beginning with the respective letters have been commonly used for other grades. These are Nancy, Mary, Kate, Isaac, Harry, George, Frank, Edward, Dolly, and Betsy. With the exception of an additional FF grade, established solely for wood rosin, the same grades apply to both gum and wood rosins (557).

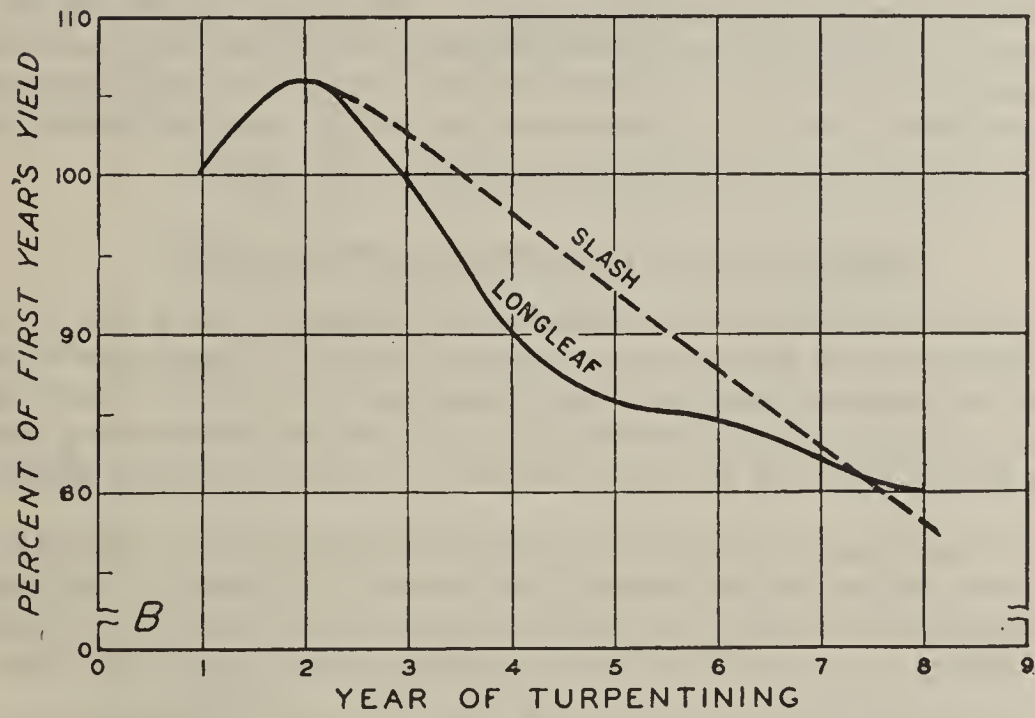
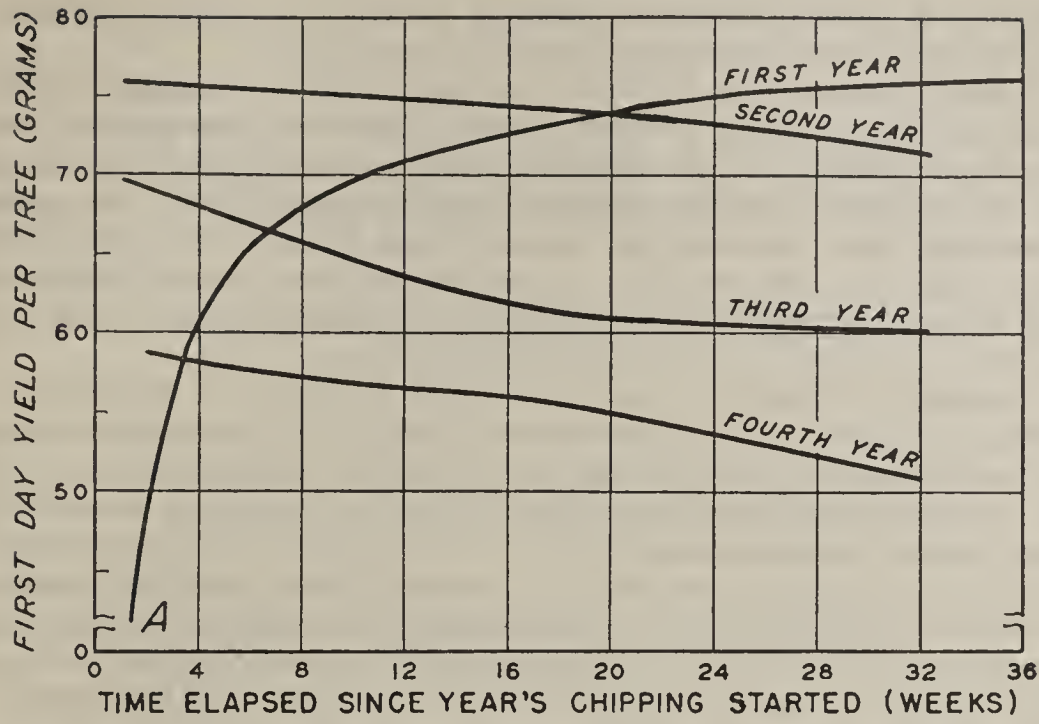


Figure 55.—Normal naval stores yields during prolonged working. *A*, trends in first-day yields following chipping of the same faces in 4 successive years; *B*, ratio of succeeding years' yields to first year's yield, showing decline in gum capacity of longleaf pine after the second year of turpentine. (After Liefeld)

slash pine,¹⁹ is graded lower, but because of a possibly larger content of desirable crystallized acids it may become more valuable commercially.

A study by Osborne²⁰ in the Olustee Experimental Forest in northeastern Florida indicates that gum dipped at 4-week intervals produces the same grade of rosin as that dipped weekly. The rosin from gum was four grades higher with increased yields and two grades lower with increased lengths of turpentine face. The quality of rosin from scrape improved with increased length of face. The proportion of oleoresin collected in the form of scrape depended on total quantity yielded and length of face; the greatest proportion of scrape was associated with low yields and long faces.

Altogether, the quality of naval stores yields is affected by the interval of chipping, the height of face, and the amount of yield, but as these factors change, their combined effects in irregular stands are difficult to determine without actual tests. A gain from one cause is often offset by a loss from another, or attained only through increased production costs. Hence the relative merits of different techniques discussed in this chapter are best judged on the basis of profit or loss to the operation.

The data in Table 50 show qualitative variations and profit and loss caused by differences in yields and by the position of cups. It is noteworthy that the larger yields are usually accompanied by the better grades of rosin. The last column of Table 50 indicates that the boundary between profit and loss in 1935 was between 30 and 35 units when cups were raised annually, and between 35 and 40 units when they were not. This boundary, however, fluctuates with shifting labor costs and prices at the still.²¹ Nevertheless, it is true that the working of high-yielding timber and the annual raising of cups reduce costs per unit of production, improve the quality of the products, and thus augment the returns to the operator.

IMPROVING NAVAL STORES PRACTICES

Turpentine methods should be efficient and profitable as well as conservative, maintaining a sensible balance between immediate profits and future values of the timber. In this respect, conservative and prolonged working of a tree is not always the best policy, but severe turpentine is only advisable for inferior trees in order to get the most from them in a short time prior to cutting them for other products (79).

As already noted, trees chosen for turpentine should be over 9 inches d.b.h., open-grown, well-spaced, heavy-crowned, and unscorched. Relatively narrow faces, covering not over one-third of the circumference, are most desirable. These should be worked one at a time, with back faces preceded by at least 1 year of rest. Streaks

¹⁹Otte, B. J. H. A study of the composition of the oleoresin of *Pinus palustris* and *Pinus heterophylla* from high, medium, and low yielding trees. 1930. Master's thesis. University of Florida. [Unpublished.]

²⁰Osborne, J. G. A study of the properties of oleoresin from longleaf pine. 1938. Address before Annual Meeting New Orleans Acad. Sci.

The oleoresin yielded by 99 longleaf pines was measured and distilled. Lengths of turpentine faces installed at the beginning of the study ranged from 3 to 32 inches. The cups of 49 of the trees were dipped weekly, the remainder at 4-week intervals.

²¹It was unprofitable in 1935 to operate timber yielding less than 35 barrels per crop, and 3 years later even 40-barrel timber was barely profitable.

Table 50.—Yields, costs, and returns from operating longleaf pine timber yielding 20, 25, 30, . . . 65 units of naval stores per crop of 10,000 faces¹ (After Osborne)

Yield of turpentine per crop			Yield per crop and grade of rosin			Value			Cost including turpentine lease	Profit or loss	
Number of units	From gum 50-gal. bbls.	From scrape	From gum	From scrape	Turpen-tine	Rosin from gum	Rosin from scrape	Total			
	Number	420-lb. bbls.	Grade	420-lb. bbls.		Grade	Dollars		Dollars	Dollars	
CUPS RAISED ANNUALLY											
20	15.7	4.3	45.34	K-M	30.63	H	472.50	301.96	202.16	976.62	1,356.36 —379.74
25	20.6	4.4	59.51	M-N	31.20	H	590.62	408.24	205.92	1,204.78	1,460.31 —255.53
30	25.5	4.5	73.84	M-N	31.62	H	708.75	531.65	208.69	1,449.09	1,564.26 —115.17
35	30.6	4.4	88.41	N-WG	31.27	H	826.88	664.84	206.38	1,698.10	1,666.91 31.19
40	35.6	4.4	103.06	WG	30.91	H	945.00	801.81	204.01	1,950.82	1,770.21 180.61
45	40.3	4.7	116.32	WG-WW	33.61	H	1,063.12	952.66	221.83	2,237.61	1,875.46 362.15
50	44.9	5.1	129.76	WG-WW	36.16	H	1,181.25	1,139.29	238.66	2,559.20	1,981.36 577.84
55	49.0	6.0	141.67	WW	42.54	H	1,299.38	1,297.70	279.91	2,876.99	2,090.51 786.48
60	53.0	7.0	153.31	WW-X	49.28	H	1,417.50	1,410.45	324.26	3,152.21	2,200.31 951.90
65	56.8	8.2	164.18	WW-X	58.07	H	1,535.62	1,517.02	382.10	3,434.74	2,311.41 1,123.33
CUPS NOT RAISED											
20	12.4	5.7	35.84	I	40.41	H-I	427.61	236.54	266.71	930.86	1,264.70 —333.84
25	15.7	6.5	45.37	I-K	46.08	H-I	524.48	299.44	304.13	1,128.05	1,359.11 —231.06
30	19.4	7.1	56.07	K	50.34	H-I	626.06	370.06	332.24	1,328.36	1,455.35 —126.99
35	23.1	7.7	66.76	K-M	54.59	H-I	727.65	441.95	360.29	1,529.89	1,551.59 — 21.70
40	26.8	8.2	77.45	K-M	58.14	H-I	826.88	514.27	383.72	1,724.87	1,645.61 79.26
45	31.2	8.7	90.17	M	61.68	H-I	942.64	605.94	407.09	1,955.67	1,750.59 205.08
50	35.4	9.3	102.31	M-N	65.94	H-I	1,056.04	721.29	435.20	2,212.53	1,854.66 357.87
55	39.4	10.2	113.87	N	72.32	H-I	1,171.80	835.81	477.31	2,484.92	1,962.25 522.67
60	43.6	11.1	126.00	N-WG	78.70	H-I	1,292.29	952.56	519.42	2,764.27	2,072.96 691.31
65	47.5	12.2	137.28	N-WG	86.50	H-I	1,410.41	1,066.67	570.90	3,047.98	2,183.41 864.57

¹Prices and costs as of April 1935.

$\frac{1}{2}$ inch deep and $\frac{1}{4}$ to $\frac{1}{2}$ inch high should be chipped at frequencies suited to the season. Tins nailed on, rather than inserted in an incision, should be raised yearly until a maximum height of 5 or 6 feet from the base of the tree is reached. Under such conditions, the annual mortality in second-growth timber should not exceed 0.5 percent of the stand (522, 624, 630).²²

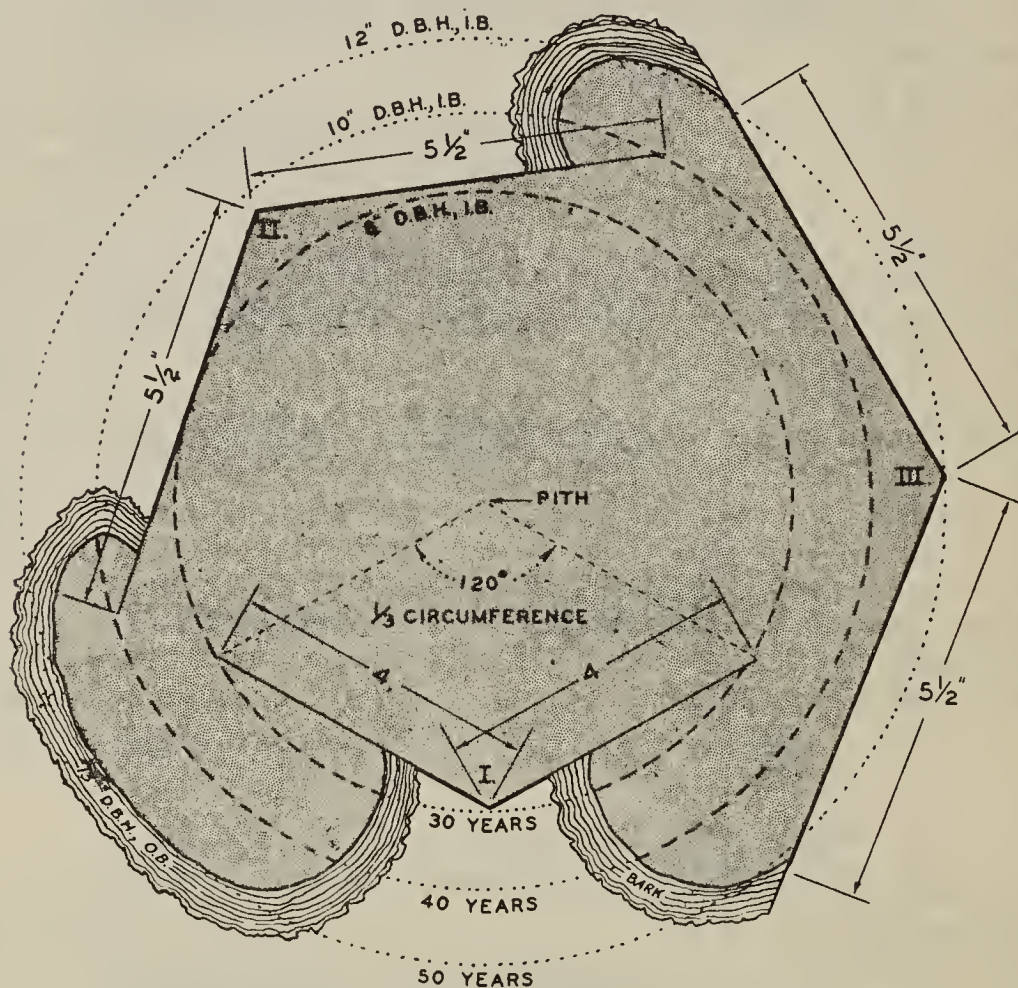


Figure 56.—A progressive and conservative 3-face method of turpentine designed for the Osceola National Forest. The cross section shows, I, the 8-inch, 30-year face of 20 years ago now largely grown over; II, the 11-inch, 40-year face partially healed; and III, the 11-inch, 50-year face being worked. Based on growth of 2 inches in 10 years, starting with a diameter of 8 inches inside bark. (After Hadley)

A scheme for using three successive and progressively healing faces is illustrated in Figure 56. This procedure is recommended only for trees 14 inches d.b.h. or larger.

Chemical Stimulation

To conserve timber, labor, or both, chemicals may be applied to the tree to extend the flow of gum from longleaf pine or to stimulate the flow of slash pine. Although the reaction is somewhat different, the effect is favorable for both species.

²²Under the Naval Stores Conservation Program, administered by the U. S. Forest Service for the Agricultural Adjustment Agency, some 3,000 producers in 1944 received subsidies for conservative turpentine practices. These involved 85 percent of the production.

Stimulation or extension reaches a maximum during July and August and declines thereafter. It is now possible to maintain yields with half the usual number of streaks by applying a 60-percent sulphuric acid solution to the streaks.

Operators who are short of chipping labor can thus obtain approximately normal yields by letting each chipper work two crops in alternate weeks. This conserves timber because through biweekly chipping the maximum face height is reached only half as fast as through weekly chipping. No serious chemical or physical changes in the gum or its products have been detected as a result of sulphuric-acid application. A cloudiness sometimes appears in the rosin, but it can be avoided by washing the gum with water (a standard procedure at central distillation plants) or, in the case of fire stills, by blending with gum from untreated trees. Use of acid after about October 1 is unprofitable.²³

The addition of arsenic inhibits the corrosion of iron by sulphuric acid and further increases the yield of gum (509). It is possible, however, that it may lower rosin grades or have some other unforeseen disadvantage. Sodium hydroxide (caustic soda) also stimulates gum flow but does not lengthen the period of exudation (347). On the whole, sulphuric acid seems to work better. Bark chipping—the removal of bark down to but not including any wood—together with acid treatment, results in yields equal to or greater than those from treated deep chipping. As compared with standard chipping without chemicals, bark chipping with chemicals is expected to increase yields about 60 percent and net profits per crop about \$1,800 at wartime prices. After acid has been applied to each of about 20 weekly bark streaks, the increased yield begins to fall off. Then chemical treatment can be discontinued for the rest of the season, leaving the trees in better condition to respond to renewed chemical stimulation the following year (510).

SUMMARY

In naval stores production proper techniques are essential for both forest conservation and business success. It is inadvisable to place first faces on trees under 9 inches in diameter and second faces on trees under 14 inches. The use of one face at a time, irrespective of tree diameter, is recommended. Faces should not cover more than one-third the circumference of the tree, nor exceed 12 inches in width, regardless of tree size. On the whole, timber stands—but not all trees—should be worked conservatively. It is desirable to turpentine certain inferior trees intensively, then remove them from the stand. As a rule, conservative procedures bring reasonable profits without jeopardizing future timber values. Following this principle, trees should be carefully selected for turpentering. Streaks should be $\frac{1}{2}$ inch deep and $\frac{1}{4}$ to $\frac{1}{2}$ inch high, chipped at frequencies suited to the season. By such methods the annual rate of mortality in second-growth stands may be kept down to 0.5 percent during 20 or 25 years of turpentering. The annual decline in the yield of 40-barrel timber may then not exceed $1\frac{1}{2}$ barrels of turpentine. Streaks that are oversize in any or all dimensions eventually reduce yields because they overwork and weaken

²³The color and condition of the living inner bark just above a treated streak are reliable indicators of the thoroughness of the application. The discoloration caused by acid penetration of the white inner bark can be readily observed by making a few vertical incisions on sample trees.

the trees. Heavy chipping delays the growth of new tissue, both resin-producing cells and wood fibers.

Longleaf pine is superior to slash pine in resisting abusive treatment and dry face. Heavy working, however, increases dry facing and mortality in longleaf, thus reducing yields of both gum and wood, and decreasing profits.

Cutting an advanced streak several weeks before regular first-year work starts usually increases single-season gum yields about 3 percent. Tacking gutters onto shallow streaks, instead of inserting them into ax incisions, increases first-year yields 25 percent or more. Following a winter's rest, jump streaks properly applied to turpentine crops in inland regions usually reduce waste and lower costs. Pines may be worked lightly in winter, but gum yield is generally small. The best chipping schedule for longleaf pine is once every other week in spring and fall, weekly in summer, and if performed in winter, once in 3 weeks.

When working faces are scorched by fire and tops are defoliated by heat or flame, gum yields decline roughly in proportion to the extent of injuries. If fire destroys two-thirds of the foliage, turpentineing should be discontinued for the season in order to permit the tree to recover. All working faces, and if practicable all unburned faces that are resting, should be protected by raking before the littered ground surface is burned. This treatment guards trees against the weakening and degrading effects of fire.

Average gum yields usually increase in proportion to the diameter of the tree (slash being superior to longleaf) and sometimes with the use of jump streaks. The yields from second faces or back faces, however, depend not only on tree size, but also on the aggregate width of the bark bars (strips of live wood between faces). Yields of turpentine and rosin can be increased 25 to 30 percent if the trees are in open rather than in crowded stands.

Crude gum scraped from the faces of pines is less valuable than that dipped from cups hung on the trees because it yields less turpentine and lower grades of rosin. Less scrape in proportion to dip is obtained when faces are short and yields high. The benefits of a short face are derived by using low streaks that extend faces upward slowly, or by raising tins, or both.

The rosin from longleaf pine, being darker colored than that from slash pine, is graded lower, but, because of a larger content of crystallized acids, may be more valuable commercially. Operating profits, however, can be augmented by working high-yielding timber and raising cups annually. This increases yields, reduces per-unit costs, and improves the quality of the products.

Chemical treatment of freshly cut streaks augments gum yields. Sulphuric-acid applications usually increase both the rate and duration of gum flow. Normal yields can thus be maintained with less labor because only about half as many streaks are needed. The newly developed technique of bark chipping and acid treatment of average timber on a weekly schedule should produce increases of 60 percent or more in yields and additional net profits of more than \$1,800 per crop each season at wartime prices.

XI. Growth and Yield of Longleaf Pine Trees and Stands

A TIMBER stand should have enough stems per acre to make full use of the soil. The form and density of the forest as a whole suggest the system of silviculture that can be most readily applied. To appreciate the possibility of obtaining increased yields it is necessary to understand differences between old growth and second growth, and to estimate the capacity for improvement in existing growing stocks.

DEVELOPMENT OF INDIVIDUAL TREES

It is reasonable to assume that for the same age and site the development of second-growth longleaf pine will be essentially the same as that of old growth, or possibly better if properly managed.

Stems

According to Bryant (58), under favorable circumstances in the virgin forest it required 85 years from seed for a longleaf pine to reach a 12-inch diameter, and 108 years to attain 15 inches. At 150 years, longleaf pine commonly exceeded 90 feet in height and averaged 20 inches in diameter (Fig. 57). In the Calcasieu region of Louisiana, embracing the parishes of Calcasieu, Rapides, Beauregard, Vernon, Allen, Jefferson Davis, Acadia, and Evangeline, old-growth trees averaged about 110 feet in height and 20 inches in diameter (263). Most of the prime logs—that is, those 15 inches or more in diameter and 24 feet long—were cut from trees that were 150 to 200 years old. These had been seedlings in early colonial days.

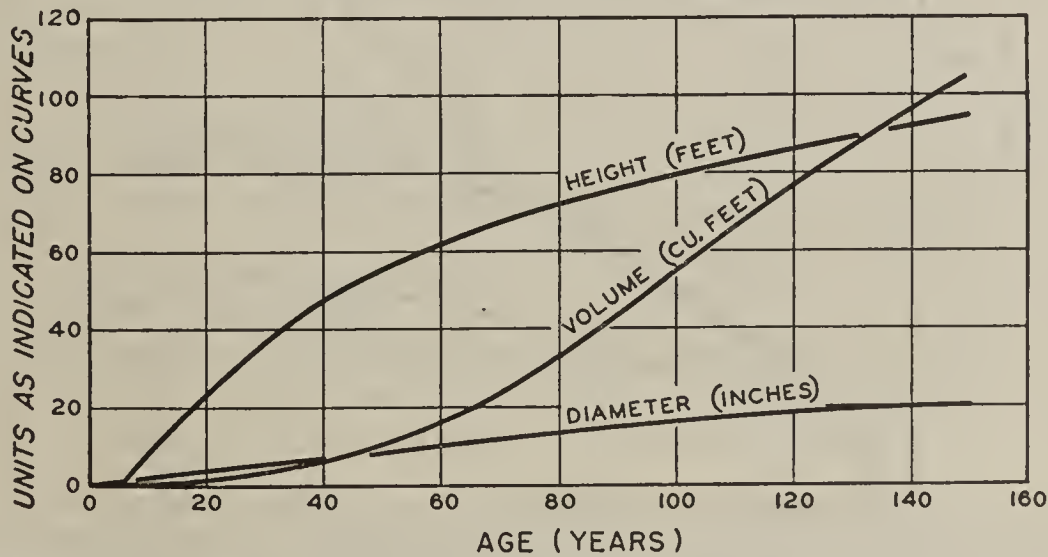


Figure 57.—Height, diameter, and volume of virgin longleaf in relation to age. (After Fernow and Johnson)

Large areas of the virgin forest were understocked, but the trees showed evidence of crowding in early life and this contributed two elements of commercial value—fullness of bole and length of clear stem. Average clear height for trees 4 to 30 inches in diameter showed that, for a given diameter, the clear length increased in the following order among southern pines: pond, loblolly, longleaf, and slash (497). Old-growth longleaf pines were one-half to two-thirds clear (Fig. 58).

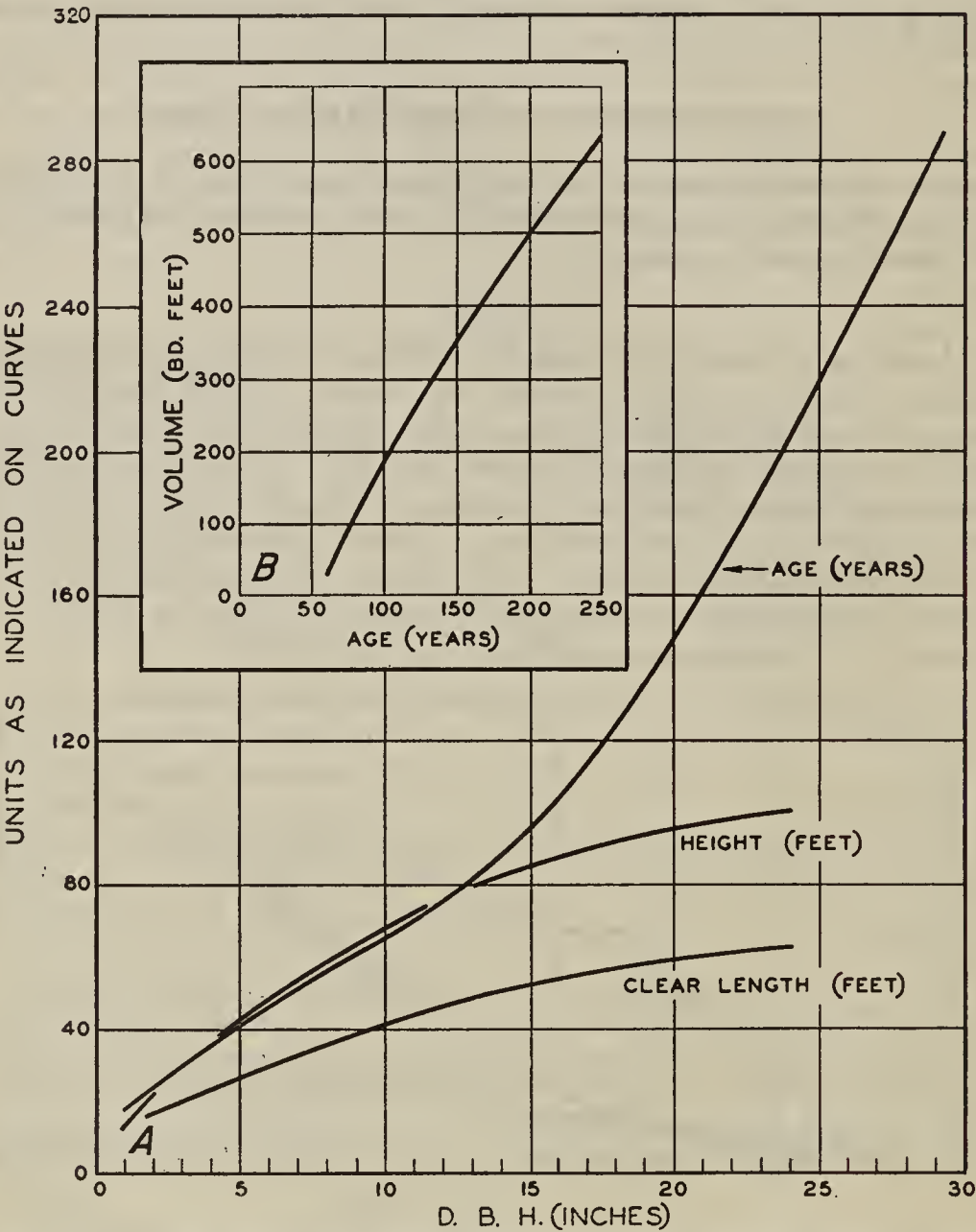


Figure 58.—A, age and stem development of virgin longleaf pines in relation to diameter. B, board-foot volume of longleaf in relation to age 60 years and over. (After Fernow and Johnson)

The Forest Survey found that second-growth longleaf stands in central Georgia in 1935 contained 45 percent smooth, 49 percent limby, and 6 percent rough trees.¹ Old-growth longleaf in the same region was much superior in quality, with 95 percent smooth, 5 percent limby, and no rough trees. Old- and new-growth trees together averaged 67 percent smooth, 30 percent limby, and 3 percent rough. Similar conditions were reported in longleaf stands in southeastern Texas, the only other locality for which information of this kind is available.

Stem form is greatly affected by the age of the tree, density of stand, and exposure to wind. Annual fires may increase butt swell slightly in the first foot above ground (8), but diameter growth in young defoliated trees is generally most retarded in the lower part of the stem. Hence, repeated defoliation may cause such trees to lose some of their normal taper, just as many suppressed trees do. Forest-grown trees taper less than others in the clear portion of the bole and more rapidly in the tops. As Figure 59 shows, the smallest trees are most nearly conical. There is a tendency, especially in closed stands, toward development of fuller boles in later life, since growth decelerates earlier in the lower than in the upper sections of the stem (Fig. 60) (489). However, the sudden liberation of forest-grown longleaf trees by heavy cutting tends to reverse this growth relationship. The lower bole of nearly all released trees begins to grow more rapidly, concentrating wood formation near the base and thus tending gradually to acquire a more youthful (conical) stem form. Increased tapers are naturally manifest first on the smaller and more rapidly growing individuals.

Root Development²

Longleaf pine normally has a massive shaft-like taproot that anchors the tree firmly against the wind. A hardpan layer in the soil, however, may arrest the penetration of the taproot and produce the stumplike formation illustrated in Plate 42. This common condition retards growth and subjects the trees to windthrow. Taproots absorb little moisture, but deep secondary roots favor independent growth and dominance.

The roots of a mature longleaf pine (Fig. 61, A) excavated in northern Florida, on a semihardpan phase of Blanton fine sand, were studied by Liefeld. The semihardpan consisted of a compact dark gray layer at 4 to 5 feet below the surface, pervious to water and root penetration, as indicated by a maximum root depth of 8.7 feet (Fig. 61, B). Lateral roots were limited by the competition of neighboring trees (Fig. 61, C), and none originated below the 26-inch level. Most of them grew within one foot of the surface. Numerous fibrous vertical branches, however, entered the second foot or deeper layers of soil. The longest of 28 main lateral roots measured 87.4 feet; the average lateral root spread was 45 feet in radius, indicating that about 1/7 acre of soil was occupied—though not exclusively—by this tree.

¹"Smooth trees have 20 feet or more of clear length and also at least 50 percent of their total usable length practically free of limbs and indications of knots; limby trees have at least 12 feet of clear length and 30 to 49 percent of their total usable length practically free of limbs and indications of knots; rough trees have less than 12 feet of clear length, or less than 30 percent of their total usable length, practically free of limbs and knots" (528).

²Root development of seedlings and young trees is discussed in Chapter V.

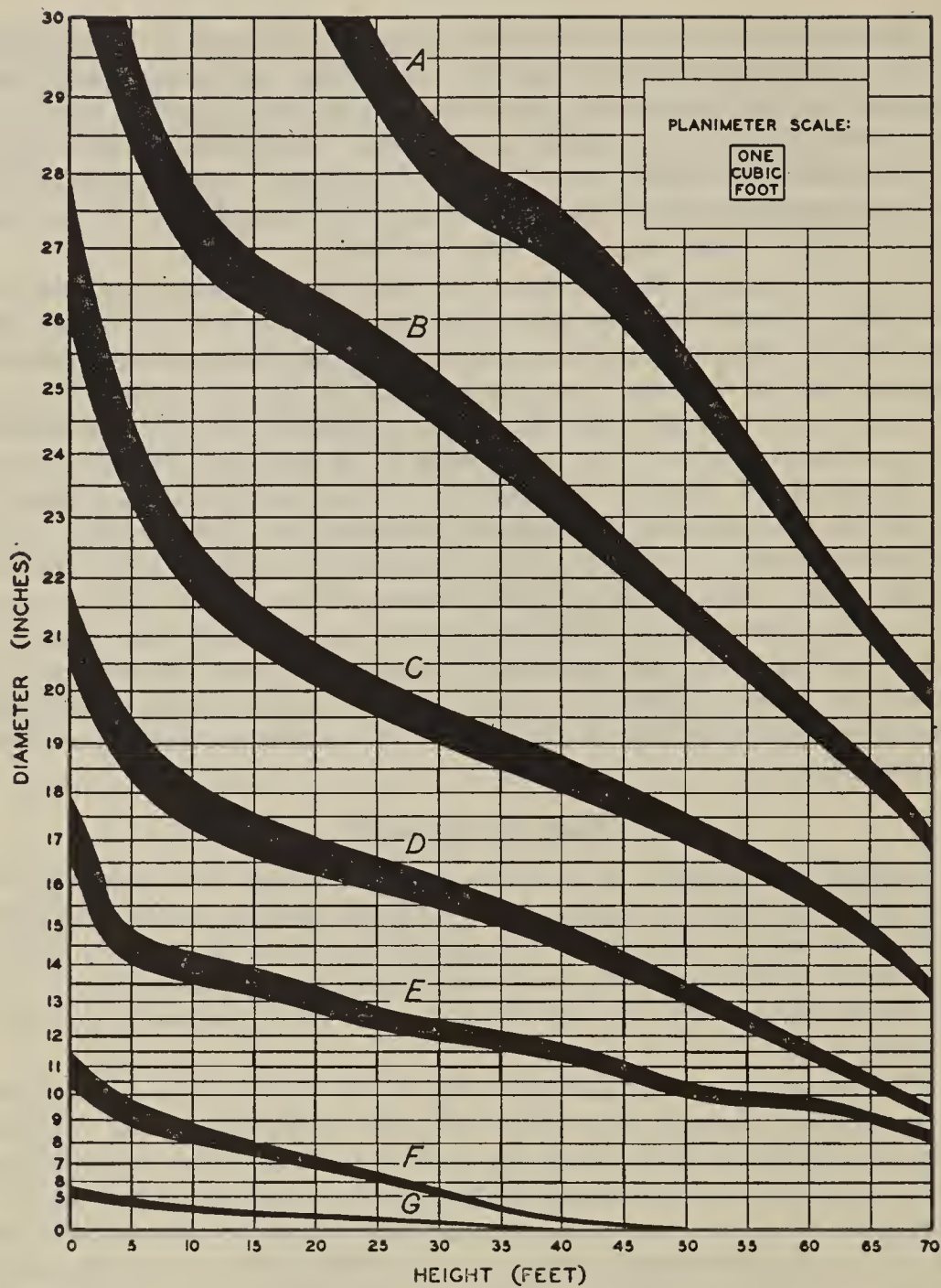


Figure 59.—Characteristic form and volume of bole and thickness of bark at different heights in seven virgin longleaf pines. Black bands represent the bark. The area under the upper edge of the band corresponds to total cubic-foot volume, that under the lower edge to the volume of wood alone.

Another large longleaf pine (Pl. 43) was excavated from the deep Norfolk sands of the longleaf pine-turkey oak type of forest in western Florida. This tree was 250 years old, 54 feet tall, and 17 inches d.b.h. It was an inch larger in diameter one foot below the surface of the soil than at breast height. The shaft measured 17

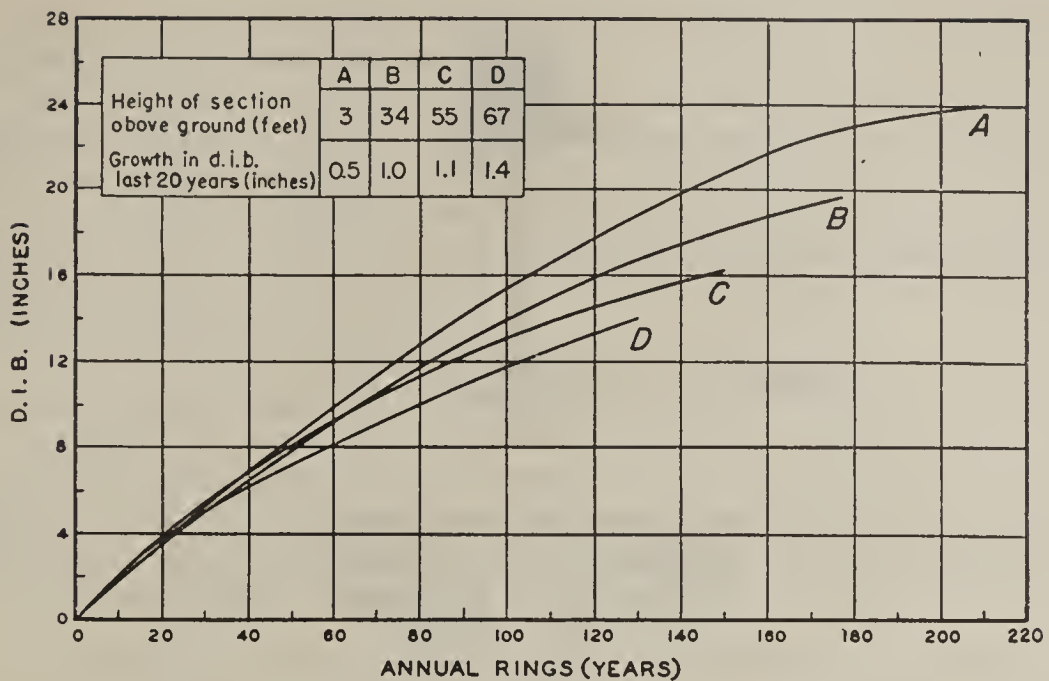


Figure 60.—Stem taper in dominant virgin longleaf pines. Note the flattening of curve *A*, indicating slower growth near the ground in later years. (After Schwarz)

inches in diameter at a depth of $5\frac{1}{2}$ feet. At 13 feet 4 inches below the surface the main root was divided into two 3-inch roots, the longer of which terminated at a depth of 14 feet 2 inches. Below this, several smaller cord-like roots penetrated undetermined depths. The fourth largest lateral root—6 inches in diameter 2 feet from the taproot—lay at a depth of 10 inches for a distance of $71\frac{1}{2}$ feet, where it descended vertically $3\frac{1}{2}$ feet, turned, and ended at a point 51 feet from the taproot.³ The lateral roots tapered rapidly to a diameter of 1 inch at a distance of 12 to 15 feet from the taproot. Beyond this point taper was slight, being nearly imperceptible in sections less than 10 feet long.

FORM AND DENSITY OF THE FOREST

The old-growth longleaf forest consisted of an aggregation of even-aged open stands, each usually covering an area ranging from a few hundred square feet to several or many acres. Longleaf pine is best suited to thrive without crowding in even-aged groups. Many of these groups originated in irregular spots where the virgin trees had been killed by bark beetles, or in strips $\frac{1}{4}$ to $\frac{1}{2}$ mile wide where tornadoes had made clearings.

Well-stocked old growth contained 30 to 100 merchantable trees per acre, although on the poorest sites, such as the extensive lowlands of the Florida peninsula,

³The reasons for occasional freakish root behavior are not known. Sometimes a spreading root will collide with an obstacle, detour to a point directly opposite, then continue in the same straight line. Others, growing normally, may abruptly reverse their course, collide with the taproot, and keep contact while growing downward 6 or 8 feet. This might be due to percolating rain. Abnormally blunt, rounded root tips may be callus-covered ends severed by rodents.

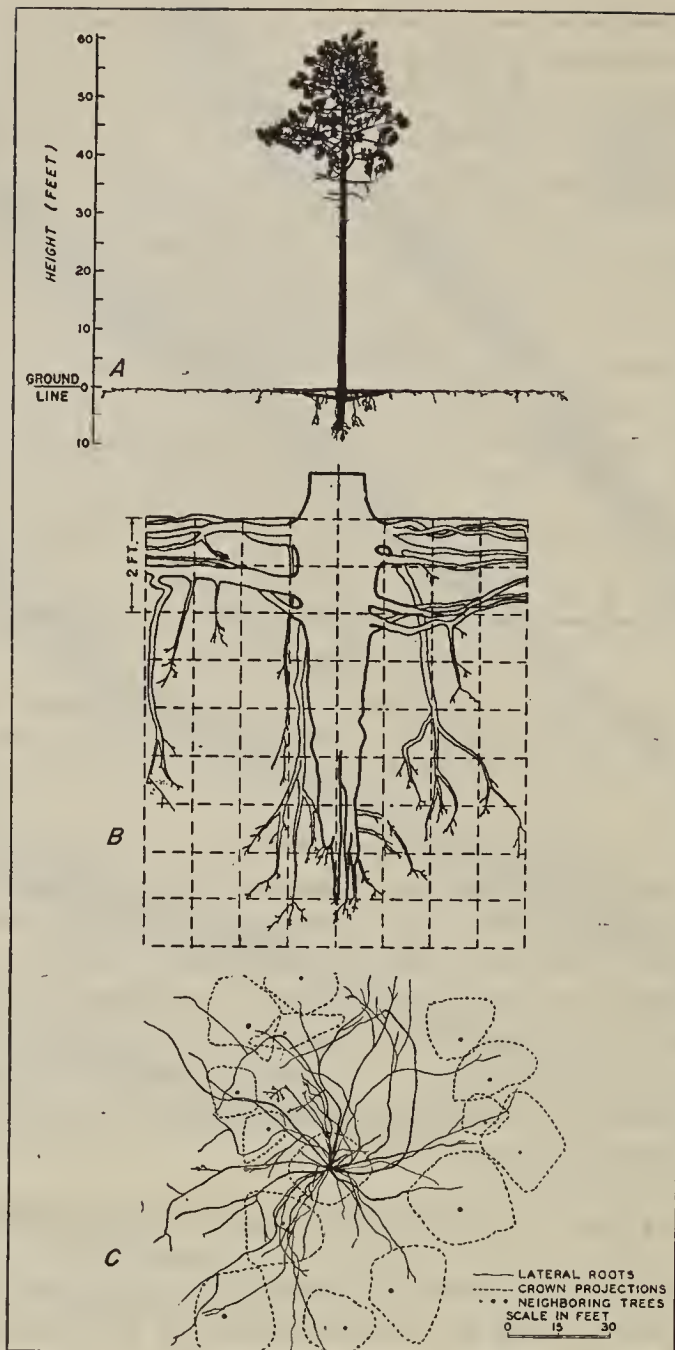


Figure 61.—Root development of a mature longleaf pine. *A*, roots, stem, and top; *B*, roots found in the vicinity of the central taproot (enlarged); *C*, root distribution in relation to neighboring trees, viewed from above. (After Liefeld)

there were only 2 or 3 trees per acre. On the deep sands of the Choctawhatchee National Forest in western Florida a site index of 30 feet in 50 years, diameter growth of 10 inches in 100 years, and high mortality among overmature trees as well as insufficient reproduction, characterized the forest. In general the drawbacks of

open stands, such as widely spreading crowns, loss of height growth, and large knots are most pronounced for the most tolerant species.

The larger size classes predominated in the virgin forests. In extensive tallies, aggregating 400 acres of old growth in Tyler County, Tex., Chapman (91) found that veteran trees 26 inches or more d.b.h. covered 16.5 percent of the area; mature trees 19 to 25 inches, 33.5 percent; young trees 12 to 18 inches, 25 percent; and immature trees under 12 inches, 25 percent. Growth and yield plots, aggregating 360 acres, showed an average volume per acre of 9,450 board feet (Doyle scale)—a good yield for large bodies of pure longleaf.

Over wide regions, the forest contained many age classes and sizes of trees; small areas were usually limited to a single age class.

Fire helped to promote the scarcity of small trees (Fig. 62) and to keep the virgin stands pure, even-aged by groups, and open. Areas cleared by wind or insects reproduced most readily because the mineral soil was periodically exposed by fire. Subsequent burning helped to lower the density of seedling—and possibly sapling—stands without providing sufficient space for another age class. Lack of small trees

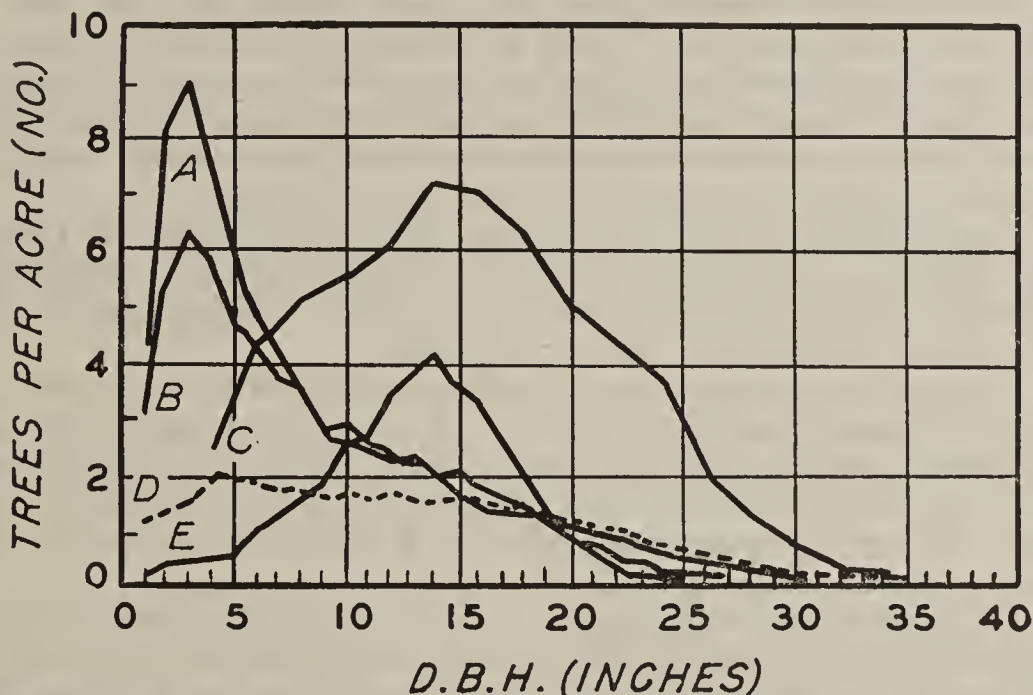


Figure 62.—Number of trees per acre of different sizes in typical virgin longleaf pine forests, in A, South Carolina; B and D, Alabama; C, Louisiana; and E, Florida. Based on samples of 124 to 2651 acres and representing 1/20 of each forest. (182)

is attributed not only to fire but to the associated effects of hog damage and vegetative competition. Heavy natural thinning in mature longleaf pine forests, and the consequent wide spacing of trees, is mainly the result of root competition.

Where longleaf saplings have ample light and root space, growth is good even on rather dry soils, burned over or not. According to Chapman (91, 92), young stands of longleaf pine on such sites should be stocked, at most, with about twice as many saplings as will be standing as mature trees at the end of a rotation period. On

moister sites, considerably denser initial stands of saplings are satisfactory. In fact, the strong early expression of dominance in stands of saplings and small poles permits close spacing in early life, and promotes early natural pruning and the clear stems needed for high-quality timber.

GROWTH RELATIONSHIPS

On moist soils the rate of growth, density of stocking, and yield at any given age tend to be lower for longleaf than for loblolly or shortleaf pines. On the drier lands, however, longleaf pine is capable of producing as much as or more volume than other pines.

Capacity for Growth

The capacity of longleaf for sustained production was manifest in old growth. For example, in Berkeley County, S. C., the diameter growth of longleaf for the first 70 years was only about half as fast as that of loblolly, but at 100 years it was three-fifths as fast, and in the second century it almost equaled loblolly (90). The current or mean periodic diameter growth was 1.8 to 1.9 inches per decade up to 80 years, then gradually declined to 1.0 inch at 120 years. After the first 50 years such trees grew 32 to 42 board feet per decade and maintained this rate up to at least 120 years. Mortality became appreciable among trees over 100 years old. Since volume growth per acre apparently culminates between 80 and 100 years, there seems to be no justification for carrying longleaf trees into the second century.⁴

Size is preferable to age as a basis for comparing growth of trees. As Table 51 shows, growth is often maintained well into the larger diameters. However, the advisability of growing large trees depends upon stocking, decadence, and mortality in stands, and unit realization values of the products.

The nature or origin of a stand—whether it is old growth, second growth, or old field—affects the development of trees. Second-growth forests contain more sound trees, but usually produce lower-quality lumber than the virgin forest. Growth in old-field stands is more rapid at early ages but of lower quality than in other stands. The rate of increment in second growth is often nearly twice that in virgin stands.

Old-field trees are usually inferior, on the basis of size (not age), because of very large, knotty central cores. Their customary phenomenal early growth is due to slightly more fertile soil, possible benefits from former tillage, and to freedom from competition of established roots of shrubs and hardwood trees. (Even dwarf or scrubby hardwoods are absent in most old fields in the Southeast.) Mutual interference, however, starts early because the trees are large for their age and the stands even-canopied. Crowding them gradually shortens the crowns—unless the stands are thinned—and retards diameter growth, resulting in a culmination of volume increment earlier than for similar timber on cut-over areas.

On some cut-over lands the keen competition of hardwoods has increased the quality of the pines, but only at the cost of retarded early growth and sometimes

⁴This limitation does not apply to superior trees reserved during harvest cuts. Their value increment may extend well beyond 100 years.

Table 51.—*Estimated 20-year growth of typical stand of virgin longleaf pine, Tyler County, Tex., by diameter classes¹ (After Chapman)*

Present diameter breast high (inches)	Estimated diameter growth	Present volume	Estimated volume growth 20 years	
	<i>Inches</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Percent</i>
9	2.3	—	—	—
10	2.3	—	—	—
11	2.3	—	—	—
12	2.25	75	65	87
13	2.2	95	80	84
14	2.15	130	95	73
15	2.1	167	108	65
16	2.1	220	119	54
17	2.05	280	125	45
18	2.0	325	132	40
19	1.95	375	138	37
20	1.9	465	143	31
21	1.85	530	146	28
22	1.8	600	148	25
23	1.7	670	150	22
24	1.6	760	151	20
25	1.55	845	153	18
26	1.5	940	154	16
27	1.45	1,040	155	15
28	1.45	1,150	154	13
29	1.4	1,260	152	12

¹Estimates of growth in diameter are based on ring counts and measurements on several hundred stumps.

reduced stocking and hence lower pine yields. Frequent burning kills the lower branches of the pines at an early stage and thus facilitates natural pruning, but it also holds back small hardwoods so that they contribute less to the natural pruning process of pine than on unburned areas.

Effect of Temperature, Rainfall, and Irrigation on Growth

Annual growth of round longleaf and slash pines in Georgia has been observed to increase as summer temperatures decline. High temperatures from June through August are usually associated with slow growth.

On the deep sands of the Choctawhatchee National Forest it was observed that variations in spring rainfall do not noticeably affect springwood formation. On the other hand, the annual rings usually become wider with increases in precipitation between March 16 and October 15, and likewise the width of the summerwood layers increases with precipitation between June 1 or July 1 and October 15. The formation of summerwood is in direct proportion to rainfall (352).

These observations were confirmed by experiments with irrigation in the same locality (431). A fairly close correlation was found between the current soil-water supply and the formation of summerwood. The width of springwood for trees grown in irrigated plots was 50 percent greater and that of summerwood 150 percent greater than the averages for the 14 years preceding irrigation, whereas trees on unirrigated check plots showed only a slight increase in ring width. These results suggested that, in order to produce heavier and stronger wood, silvicultural measures should be taken to increase the organic content of barren soil so as to increase its capacity to retain rainwater.

The growth response of summerwood to variations in rainfall is less evident on the moister sites. In 30- to 60-year-old second-growth longleaf and on the relatively moist soils of northeastern Florida, aggregate ring width increased less than 1 percent per inch of increased monthly precipitation (488).

Turpentine and Growth

It is well known that thrifty and rapid-growing pines yield the maximum amount of naval stores. However, a tree has but a limited supply of vital energy, and overproduction of one product—whether wood, gum, seeds or foliage—may restrict another. Thus it was found that when virgin trees were boxed and chipped heavily, the life of green needles was reduced from about 3 to 2 years (462). A heavy seed crop may be accompanied by shrinkage in gum flow of 10 to 15 percent, as in 1920 (383). The tissue associated with resin production is usually formed at the expense of wood fibers near the wound, so that the amount of summerwood is frequently reduced in new growth of turpentine timber (204).

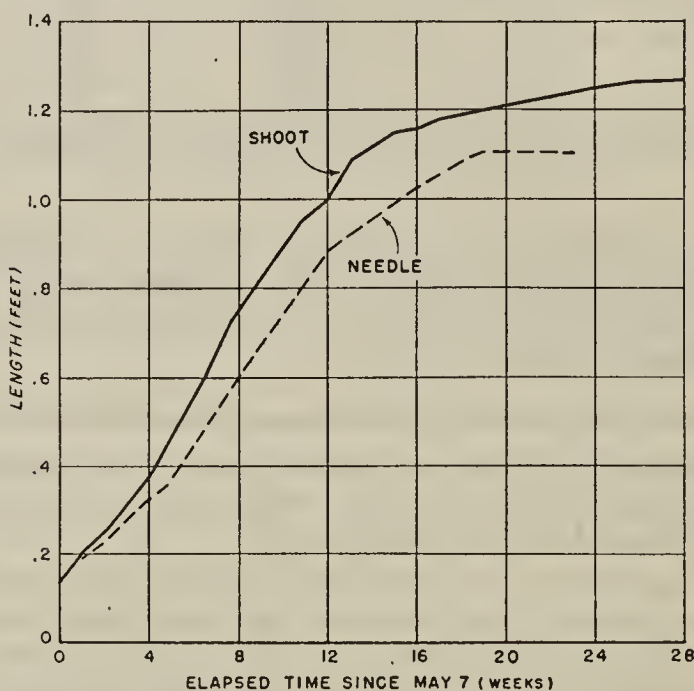


Figure 63.—Seasonal growth of needles and shoots in five longleaf pines in northern Florida. (After Liefeld)

Sometimes there appears to be a slight reduction of needle and stem growth in the middle of the growing season, during the formation of nodes or whorls. There is little or no evidence, however, that gum flow is slowed down during this time. This midseason slackening of growth is usually more apparent than real. The length-growth of leaves slows down somewhat in the fall like that of shoots and may cease in September, while shoot growth continues. For both leaves and shoots, however, and probably for gum also, summer growth is normally continuous, not intermittent (Fig. 63).

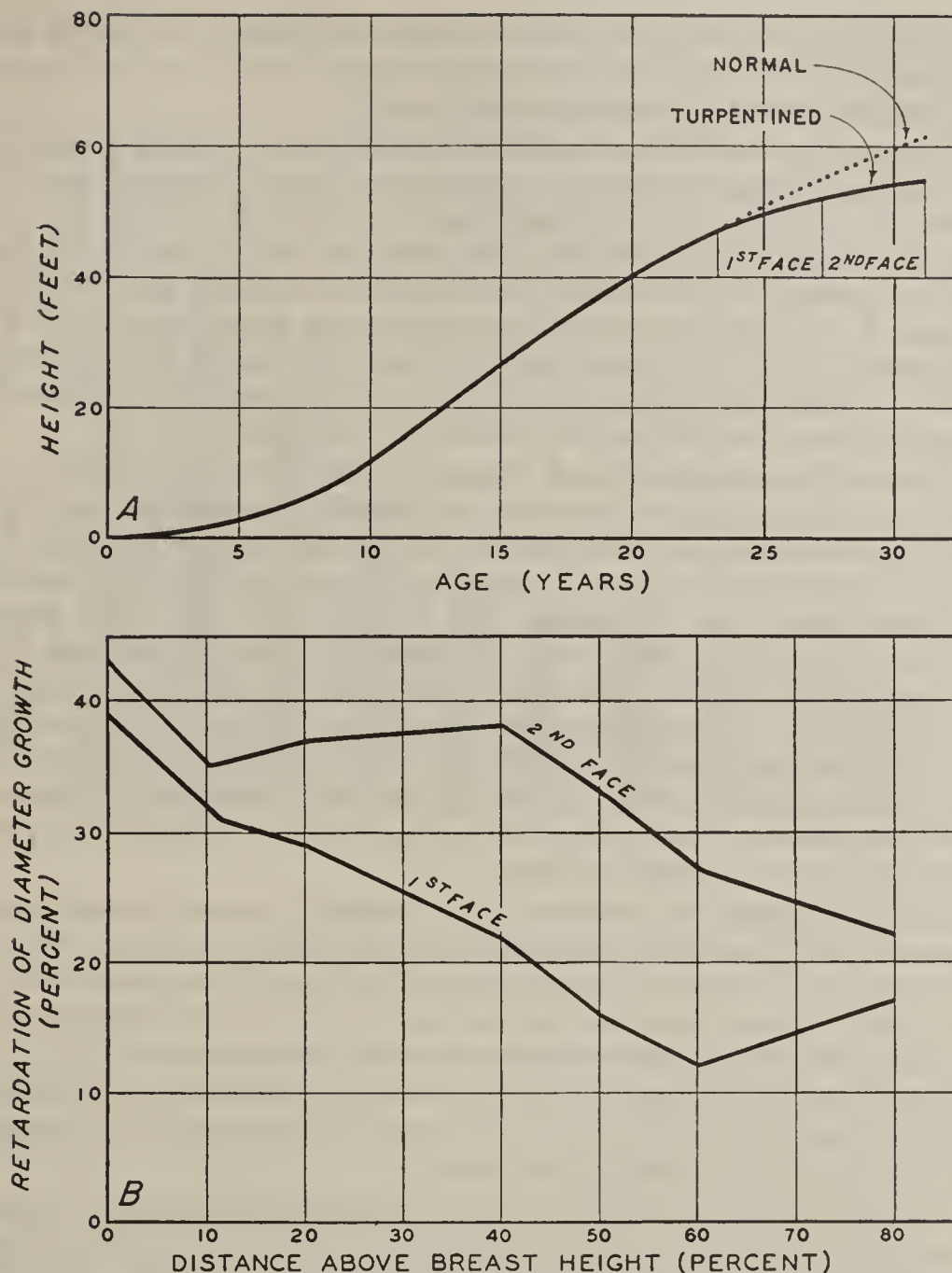


Figure 64.—Growth in height and diameter of longleaf pine as affected by turpentine. *A*, height growth of trees in Georgia; *B*, retardation of diameter growth in trees in Florida. (After Harper)

The amount of reduction in height growth due to turpentine (Fig. 64, *A*) depends on the tree and the site. No reduction could be detected in some trees growing on Leon and other hardpan soils where height was retarded by soil conditions. As might be expected, two faces cause more retardation in height growth than does one.⁵ In one instance, second-growth longleaf 11½ inches d.b.h. worked

⁵Harper, V. L. The influence of turpentine on the growth of slash and longleaf pine. 1930. U. S. Forest Service, Southern Forest Experiment Station. [Unpublished]

with 1 face for 3 seasons grew $5\frac{1}{2}$ feet in height, while similar trees having 2 faces grew only $3\frac{1}{2}$ feet (79). There was no evidence that the width or depth of streaks influenced the amount of reduction in height growth.

Chipping also causes a loss in diameter growth, and the reduction increases with the height and depth of the streaks. As with height, however, the major factor is the percentage of girth cut. It was found that for $11\frac{1}{2}$ -inch trees, those with 1 face grew 0.715 inch in 3 years while those with 2 faces grew only 0.66 inch (630). Rough estimates based on some 40 increment cores indicated a 25-percent reduction in diameter growth on 1-faced trees during heavy turpentining without recovery in the ensuing decade (224). The 2-faced trees lost 60 percent in growth and failed to recuperate. A later report (229) indicated that single faces were then reducing diameter growth about one-third, and double faces 40 to 50 percent.

Greatest loss in diameter growth in second-growth timber usually occurs at breast height, the next greatest at the top of the face, and the least above the face (Fig. 64, B). This may not be true of old-growth trees that have been making their widest rings at midstem points. Thus, in virgin timber heavily worked for 4 years, Cary (79) noted heavy losses in diameter growth even at the top of the first log. At that point diameter growth decreased 30 percent for trees with 1 face and 47 percent for those with 2 faces. Very narrow bark bars or a third face brought still further reduction. For more conservative working in old growth, it was estimated that 1 face per tree impeded growth very seriously on perhaps only 5 percent of the trees, while on another 5 percent, growth was apparently unhampered. The remaining 90 percent were variously affected, the average reduction being about 25 percent in longleaf pine, and more in slash pine.

In volume growth the retardation due to chipping 1 face on longleaf pine was between 20 and 23 percent in 3 counties in northern Florida, but reached 34 percent in a fourth county. A second face increased the loss in cubic-foot growth to 40 percent. Later estimates placed this reduction at 25 percent for the first face and 39 percent for the second, whether worked in succession or simultaneously (257).

Retardation in growth seems to be attributable to the diversion of photosynthetic products to gum rather than to wood, and to the checking of the flow of elaborated plant food or solutes in crude sap past the face.

In northeastern Florida alone the volume of wood growth lost from turpentining during 1934 (including retardation, mortality, and cull in butts) was estimated at approximately 210 million board feet, or as much as the commodity drain of all wood products of all pine species in the region (318).

GROWTH AFTER PARTIAL CUTTING

Longleaf pines on good sites possess an astonishing capacity to recuperate after heavy cutting of trees that dominate them. Figures 65 to 68, based on an analysis of surviving trees with no allowance for mortality, show the effects of release. The start of increased growth after logging depends on local growing conditions. For example, a delayed response of two or three years has been noted in certain tracts in

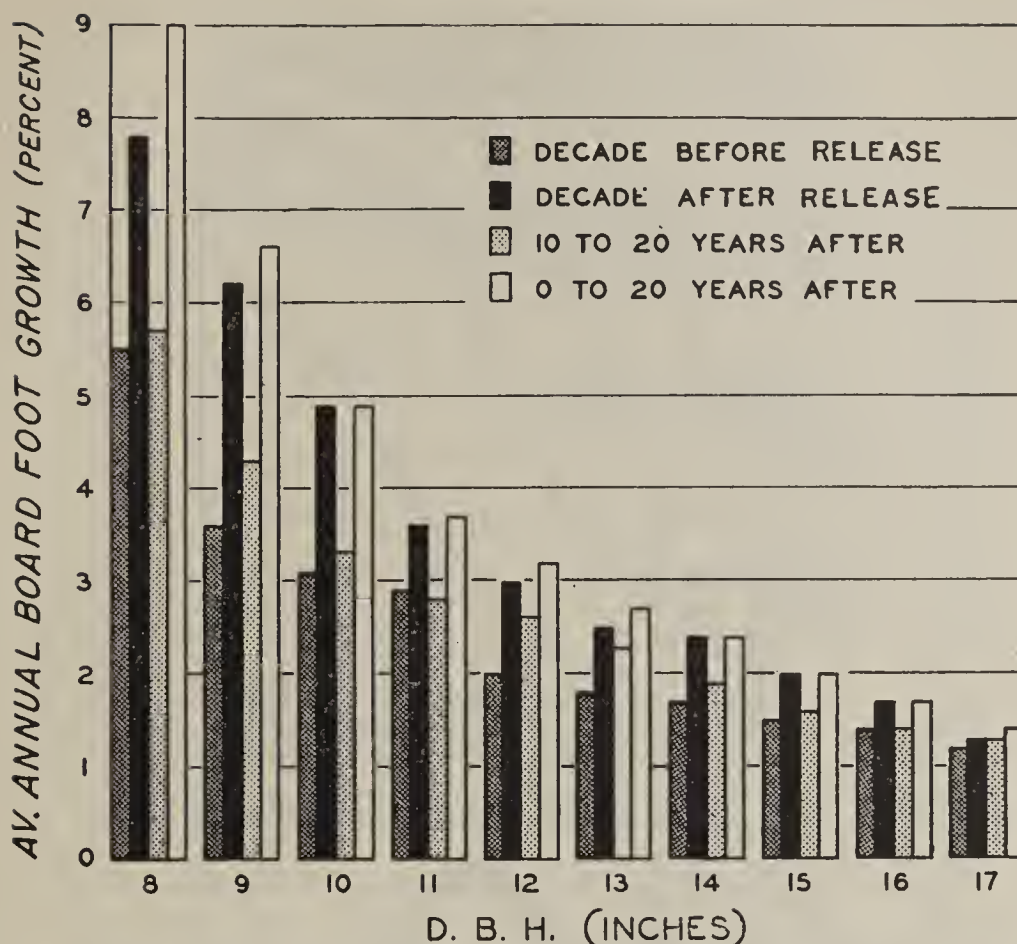


Figure 65.—Average growth in percentage of tree volume on a 70-foot site—old-growth longleaf timber released by cutting. (After Demmon)

Alabama and Louisiana (14, 181), whereas in every formerly suppressed tree examined in a study at Urania, La., increased growth had started during the first season after logging. On good sites, instant response to release is attributed to the promptness with which new feeding roots are extended to absorb the moisture and nutrients made available by removal of competitors, and to the ability of the crowns to function with greater vigor even before they have time to increase their leaf area. At Urania this immediate response from clearly substandard trees left for seed was followed by a gratifying rate of growth, although three to six years elapsed before this rate was stabilized (100, 113). Delay in growth response because of poor site is not important, in view of the certainty of substantial increases in subsequent growth.

Vigorous 35-year-old second-growth stands of longleaf, from which all merchantable trees are removed for pulpwood, seem at first to be hopelessly devastated. On many heavily cut areas in the longleaf region, some 100 to 200 suppressed spindly trees per acre less than 5 inches in diameter have been left. These trees, about the same age as those harvested, would seem unlikely to recover. After 4 or 5 years, however, even the most severely suppressed individuals resume height and diameter growth at a faster rate than at any earlier period, and give promise of a second pulp-

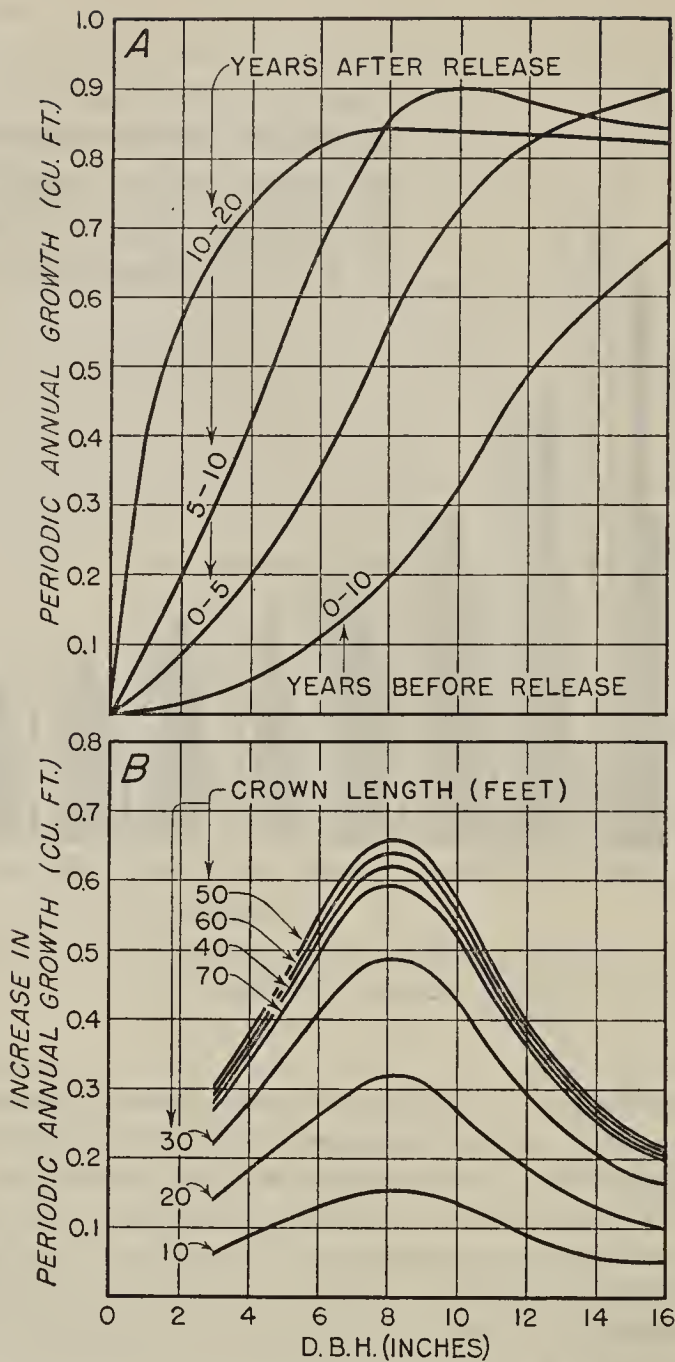


Figure 66.—A, periodic annual growth of old-growth longleaf pine seed trees, by diameter classes, for various periods before and after release; B, increase in growth after release in relation to crown length. (After Chapman and Bulchis)

wood cut within 10 or 15 years. Cuttings of this kind are not recommended, however, because in the long run far greater financial yields are attained with much lighter and more frequent cuttings.

On areas heavily cut over, some of the small leaning trees may produce a disproportionate amount of compression wood, undesirable in either pulp or lumber. Log

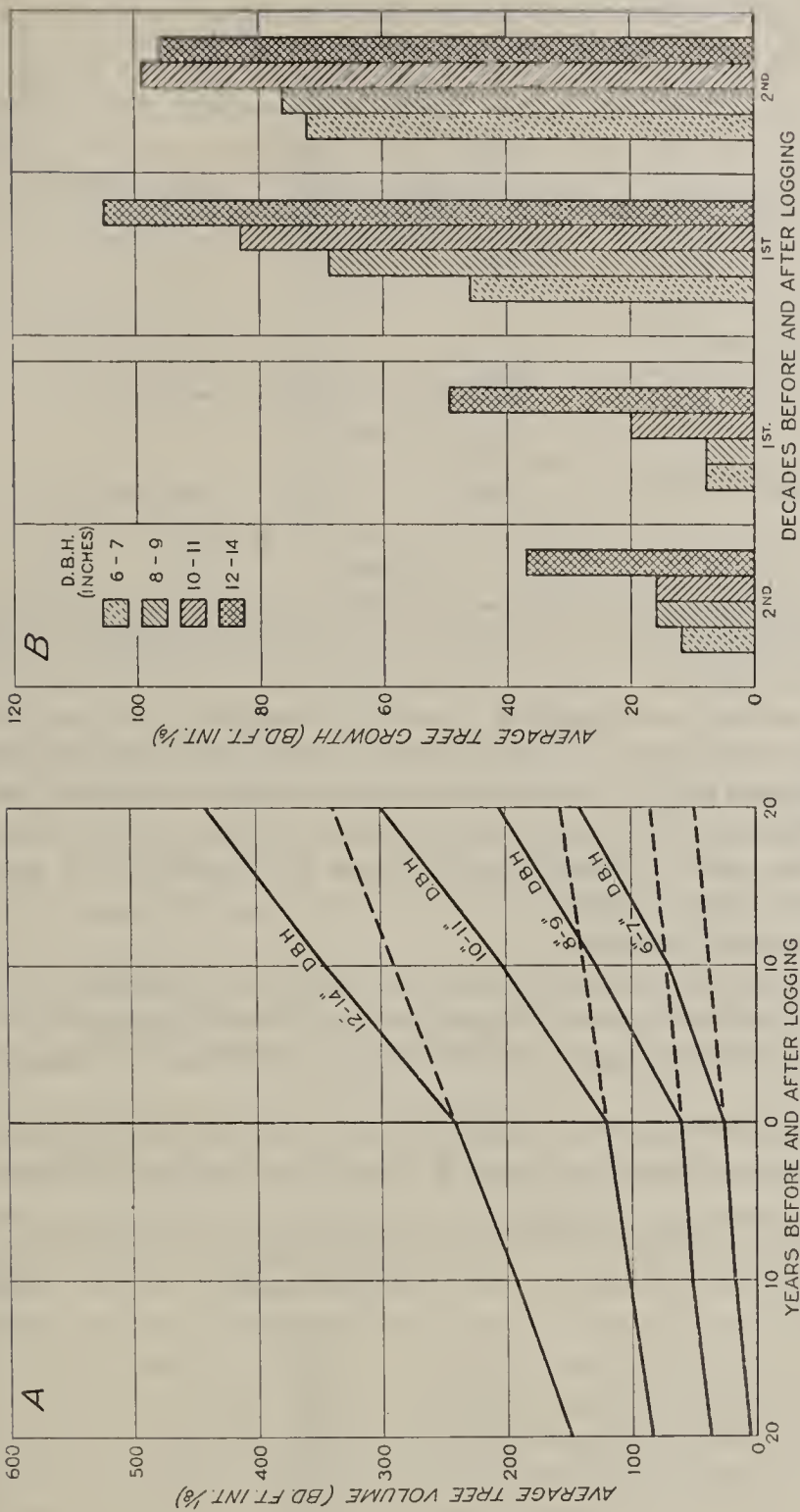


Figure 67.—A, volume, and B, growth in board feet for average old-growth longleaf pine trees, in four diameter groups, before and after release by logging. (No mortality included.) Broken lines indicate the volumes that would have been attained with no increase in growth rate. (After Barrett)

buyers may not recognize this inferior wood, which warps during seasoning. Wood of slow growth formed before release and wood of rapid growth formed after release do not warp seriously when cut from strictly perpendicular trees, and there is no loss in quality of products from straight, smooth-boled trees grown at accelerated rates.

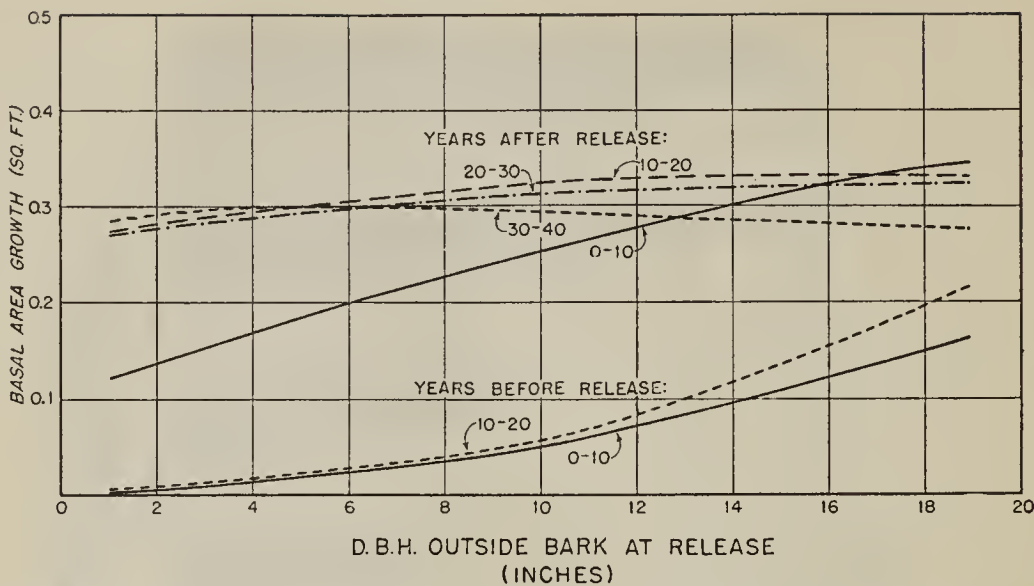


Figure 68.—Periodic annual growth in basal area of old-growth longleaf pine seed trees, by diameter classes, for various periods before and after release by logging. (After Chapman and Bulchis)

Leaning and crooked trees should be cut early. However, the values lost through lowered quality of such trees, if retained, are sometimes offset by greater volume.

Longleaf pines left on cut-over lands increase rapidly in diameter and volume (Tables 52 and 53). Values rise even more quickly. Many suppressed trees below 10 inches d.b.h. suddenly brought into the open by removal of the merchantable stand increase in value at a rate of 15 percent or more a year; if over 10 inches, at a rate of approximately 10 percent.

Accelerated growth varies, of course, with locality and treatment, and is less on the poorer sites and under partial release than on better sites and with full release. A light cutting confined largely to slow-growing subdominants brings the poorest response.

The cutting of virgin stands usually left only trees below a fixed diameter limit (181). Growth in volume of such trees in a Louisiana stand heavily logged in 1904

Table 52.—Growth in diameter of longleaf pine left in logging, by size class, Louisiana (After Ashe)

Diameter breast high at time of release (inches)	D.b.h. 10 years after release	Diameter increase
	Inches	Percent
5	7.6	52
6	8.7	45
7	9.8	40
8	10.9	36
9	12.0	33
10	13.1	31
11	14.1	28
12	15.1	26
13	16.1	24
14	17.2	23
15	18.0	20
16	18.9	18
17	19.8	16
18	20.8	16

Table 53.—*Growth in volume, Scribner rule, of cull longleaf pine, left in logging on loamy sand, interior Coastal Plain, central Louisiana (After Mattoon)*

Diameter breast high, 1902 (inches)	Volume		Growth	Increase
	1902	1917		
	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Percent</i>
7	10	80	70	700
8	20	95	75	375
9	32	114	82	256
10	45	134	89	198
11	62	157	95	153
12	83	186	103	124
13	110	223	113	103
14	142	264	122	86
15	185	315	130	70
16	235	371	136	58
17	300	445	145	48
18	375	528	153	41

has been depicted by Barrett (22). Those trees between 6 and 9 inches in diameter at the time of logging produced approximately 6 times as much lumber in 20 years after logging as in 20 years before logging. The 10- to 11-inch class produced about 5 times as much and the largest trees only twice as much. They did not respond as well as the smaller ones because they were not suppressed in the original stand (Table 54 and Fig. 67).

Chapman and Bulchis studied an area at Urania, La., logged heavily about 1901 (113). Their investigations were more definitive than previous research on accelerated growth. The development of 20 originally unmerchantable trees during 31 years following release is shown in Table 55 and Figures 66 and 68. The relatively superior growth response of small trees—noted by earlier investigators—is again manifest. The 8-inch diameter class showed the greatest response (Fig. 66, B). The rate of increase in periodic growth, as measured in square feet of basal area, rose for about 10 years for all sizes of trees released (Fig. 68). Total annual growth, as shown in Figure 66, A, became stabilized about 10 years after release for trees 12 inches and larger at time of logging. Growth then leveled off at about 0.03 square foot per year per tree, or 0.3 square foot per decade, equivalent to 0.85 cubic foot per year, or 8.5 cubic feet per decade, for all trees irrespective of diameter class.

This study indicated that where veteran trees were closely grouped, the smaller ones were badly retarded in diameter growth owing to root competition, and regardless of light conditions. Wood production per unit of crown volume nearly doubled after release. The correlation index for periodic annual growth in board feet 10 years before release in relation to crown volume was 0.658; that for growth in relation to crown length was 0.654. Chapman and Bulchis concluded that crown length indicates capacity for volume growth following release, and that trees with crowns 40 to 50 feet long produced the most rapid growth consistent with high quality (Fig. 66, B).

Data on lateral space requirements are highly useful in timber growing. In northern Louisiana the radial limit of effective root spread for mature longleaf pines was found to be about 30 feet (113). Full utilization of this space is followed by a prompt leveling off of growth and eventual death within 10 or 15 years of nearly all

Table 54.—Growth of virgin longleaf pine, Urania, La., before and after logging¹ (After Barrett)

Item	Diameter breast high (inches)				Total
	6-7	8-9	10-11	12-14	
Residual trees (actual):					
Proportional distribution _____ Percent	17.5	30.5	39.0	13.0	100.0
Average volume per tree:					
20 years before logging _____ Bd. ft.	7	38	85	151	—
10 years before logging _____ do..	19	54	101	194	—
At time of logging _____ do..	27	62	121	243	—
10 years after logging _____ do..	73	131	204	348	—
20 years after logging _____ do..	145	207	303	444	—
Average growth per tree:					
2d decade before logging _____ do..	12	16	16	43	—
1st decade before logging _____ do..	8	8	20	49	—
1st decade after logging _____ do..	46	69	83	105	—
2d decade after logging _____ do..	72	76	99	96	—
Residual stand per acre (hypothetical):					
Trees ² _____ No.	4	8	10	3	25
Volume at time of logging _____ Bd. ft.	108	496	1,210	729	2,543
Volume 10 years after logging _____ do..	292	1,048	2,040	1,044	4,424
Growth in first decade _____ do..	184	552	830	315	1,881
Volume 20 years after logging _____ do..	580	1,656	3,030	1,332	6,598
Growth in second decade _____ do..	288	608	990	288	2,174

¹Based on measurements of 50 trees (12 per acre), International 1/8-inch rule.

²Assuming that 25 well-spaced trees per acre will grow at a rate equal to that of the 12 trees per acre actually left in the stand. The original stand contained 90 to 100 trees per acre.

Table 55.—Average growth and yield of 20 virgin longleaf pine seed trees for 31 years after release by logging, Urania, La. (After Chapman and Bulchis)

STAND DESCRIPTION, 1906 and 1937

Measurements	D.b.h.	Clear length	Usable length	D.i.b. at 48 feet	Height	Age	Sawed contents	Lumber value
	Inches	Feet	Feet	Inches	Feet	Years	Bd. ft.	Dollars
At time of release (1906) _	9.2	39	48	5.5	78	81	75	1.72 ¹
31 years later (1937) _	17.7	39	48	10.1	86	112	312	10.73
Increase _	8.5	0	0	4.6	8	31	237	9.01

VOLUME AND VALUE, 1937

Grade of lumber	Volume		Value per M bd. ft.	Value per tree	
	Bd. ft.	Percent		Dollars	Percent
B and Better _	83	26.6	48	3.98	37.1
No. 1 Common _	90	28.7	40	3.58	33.3
No. 2 Common _	129	41.5	23	2.97	27.7
No. 3 Common _	10	3.2	20	.20	1.9
Total _	312	100.0	—	10.73	100.0

¹Actually no value at the time of logging in 1906, but based on an estimated value of \$23 per M board feet for No. 2 Common lumber.

younger longleaf pines within it. With competition from new trees completely excluded, the growth of residual virgin trees was stabilized at about 0.85 cubic foot per year per tree, and no deceleration occurred over a period of 31 years.

Growth Rate in Relation to Quality of Wood

The growing of a second crop of timber from the remnants of a heavily exploited longleaf pine stand has often been profitable because of accelerated growth on clean stems. In studies of cut-over forests in northern Louisiana, it was found that most of the trees were well pruned naturally by the time of cutting and release,

with clear lengths of 2 to 3 logs each. About 80 percent of the board-foot growth after logging was classified as potentially clear wood. Actually, less than 80 percent B-and-Better lumber could be sawed out because of the inclusion of knotty cores and exclusion of clear slabs.

Residual trees, most of which were subdominant in the original stands, usually bring top prices if they can meet specifications for poles or piles. Saw timber is next in value, and pulpwood or other cordwood products are least valuable. It has been

Table 56.—*Average growth rates and specific gravity of longleaf pine wood for successive growth periods under different stand conditions (After Paul)*

Item	Thinned before final growth period		Unthinned	
	La Salle Parish, La.	Walton County, Fla.	Virgin timber, S. C., Fla., Miss., La.	Second growth, S. C., Fla., La.
Number of trees	7	5	35	35
Age (years)	125	100	60 to 350	25 to 90
Initial growth period:				
Annual rings per inch	20	28	18	5
Specific gravity	0.669	0.636	0.650	0.557
Intermediate growth period:				
Annual rings per inch	33	43	26	9
Specific gravity	0.626	0.600	0.587	0.581
Final growth period:				
Annual rings per inch	11	13	31	11
Specific gravity	0.612	0.637	0.516	0.598

estimated that the originally small and inferior trees of the longleaf forest should earn at least 9 or 10 percent simple or 6 percent compound interest annually for 15 years, if harvested for the most profitable uses consistent with their individual qualities. Actually, they have brought at least 75 percent annually in northern Louisiana, owing to a 6- to 8-fold increase in stumpage price.

Uniform grain and fairly dense but not too resinous wood is desirable for pulpwood or saw timber. Dense longleaf pine wood is not always close-grained, but has high specific gravity and summerwood content, and superior strength values.⁶

A relatively good supply of summer moisture usually produces a high percentage of summerwood, regardless of the width of rings. Virgin trees occasionally, however, show comparatively rapid and dense growth in early life, followed by slower growth and less dense wood—the portion near the periphery having the most rings per inch and the lowest specific gravity (Table 56).⁷ On the other hand, second-growth timber usually has fewer rings per inch and lower specific gravity.

To observe the effects of stand density and crown size, Paul (421) compared the wood from 10 small-crowned longleaf pines in fully stocked stands with that from 10 large-crowned longleaf pines in moderately open stands. The former averaged 10 rings per inch, with springwood and summerwood about equal, and specific gravity 0.600; the latter averaged 4 rings per inch with springwood predominant

⁶Some of the causes of failure to produce such wood have been investigated by Paul (421, 422, 425, 426). He found that the specific gravity of longleaf pine wood was affected by origin (as virgin or second growth), density of stand, and moisture and fertility of the site.

⁷On very dry soil, the deficiency in moisture often results in narrow rings with a small proportion of summerwood. If summerwood bands are reduced to a single row of cells, the wood formation of consecutive springs is merged. Fortunately such wood is not common in longleaf pine.

and specific gravity 0.538. During the early years, at least, the size of the crown was the principal factor in determining specific gravity. When density changed abruptly, as in thinning, a gradual increase in crown size and decrease in specific gravity usually followed. This effect was noted only when growth conditions favored the production of springwood rather than summerwood. With favorable conditions throughout the growing season, specific gravity increased.

It may be concluded that in any longleaf stand, whether dense or open, the site and climate must be favorable for growth of summerwood if timber of high specific gravity is to be produced. Lightwood can be produced rapidly on ordinary sites, but with some sacrifice in quality, by keeping stands continuously open; heavy wood can be grown at a moderate rate, on improved or better than ordinary sites, in stands of medium stocking.

The production of wood of uniform weight, either light or heavy, requires careful attention on the part of the forester. Growing conditions should be held as constant as possible during the life of the stand, but it is not imperative to do so if leaning trees are eliminated. Sudden release induces sharp contrasts in wood structure, which may seriously affect the quality of products sawed from leaning trees. On the other hand, boards sawed from vertical trees several years after release from competition do not seem to have serious crook, bow, twist, cup, or other common defects (422, 430).

YIELDS

Virgin Timber

On the poorest sites, the deep and sterile sands of parts of Florida and the Carolinas, trees in the original longleaf forest were widely spaced, yielding perhaps only 2 or 3 M board feet per acre. Elsewhere on poor sites, longleaf stands yielded about twice as much volume. On better sites, with a clay subsoil and fairly well drained, as on extensive areas in Texas, Louisiana, and Mississippi, yields were about 8 to 12 M board feet per acre. Such forests were pure and largely mature, but patchy—broken by openings and stands of younger trees originating in spots cleared as a result of insects or high winds. On the best sites, and where the forest was unbroken, yields were 20 to 30 M board feet per acre. There are now only scattered remnants of these high-yielding stands—the accumulation of centuries.

The new second-growth forests still contain many individual old-growth trees which were unmerchantable in the original harvest because of defects or small size. Many of these inferior individuals grew rapidly and subsequently became highly valuable, both for reseedling and commercial use. Such trees, however, are not typical of virgin or second-growth forests and will not be found in future rotations. They will be cut to make room for better trees.

Although the gross yields from virgin stands in their second and third centuries will not generally be realized from managed second-growth stands, old-growth quality will be found in certain trees retained over two rotation periods. As a rule, such trees will be sound, straight, clear-stemmed, and superior for sawlogs, veneer logs, or other high-grade use. Uncrowded trees of this kind will grow much faster than old-growth trees, but in the second rotation may be expected to resemble virgin timber.

The board-foot volumes typical of virgin longleaf of merchantable sizes were determined by Chapman in a study made in Texas (91). Most of the trees had a merchantable length of 3½ logs. All trees over 16 inches in diameter had 2½ logs or more; no trees under 20 inches had as many as 5 logs. There were about 32 trees

Table 57.—Average volume per tree and number of trees per 40 acres, typical virgin longleaf pine stand, Tyler County, Tex. (After Chapman)¹

Diameter breast high (inches)	Volumes by merchantable lengths in number of 16-foot logs—							Stand on 40 acres by number of 16-foot logs—							Total
	2	2½	3	3½	4	4½	5	2	2½	3	3½	4	4½	5	
	Board feet (Doyle rule)							Number of trees							
12	65	75	85	—	—	—	—	65	39	26	—	—	—	—	130
13	80	95	105	120	135	—	—	34	35	34	12	—	—	—	115
14	90	110	130	150	170	—	—	34	55	28	14	7	—	—	138
15	105	130	155	180	205	235	—	17	41	28	17	11	—	—	114
16	125	155	190	220	255	290	—	11	22	33	22	22	—	—	110
17	150	185	220	260	300	340	—	—	18	27	23	18	5	—	91
18	175	215	260	300	350	390	430	—	10	25	31	31	5	—	102
19	200	250	300	350	405	455	500	—	4	8	29	33	8	—	82
20	230	285	345	410	465	525	580	—	—	9	26	31	22	—	88
21	265	330	395	460	530	600	665	—	3	7	22	25	11	3	71
22	—	375	445	525	600	680	750	—	—	6	30	12	6	6	60
23	—	410	500	590	670	750	835	—	2	11	11	7	4	2	37
24	—	—	570	670	760	850	935	—	—	3	8	14	3	—	28
25	—	—	640	740	845	940	1,035	—	—	5	6	8	3	6	28
26	—	—	725	830	940	1,040	1,145	—	—	4	4	8	4	—	20
27	—	—	825	930	1,040	1,150	1,265	—	—	1	3	4	2	—	10
28	—	—	915	1,030	1,150	1,270	1,390	—	2	1	2	4	2	—	11
29	—	—	995	1,125	1,260	1,390	1,525	—	—	—	2	1	5	2	10
30	—	—	1,080	1,220	1,360	1,510	1,665	—	—	—	2	3	3	2	10
31	—	—	—	1,320	1,480	1,640	—	—	—	—	—	2	2	—	4
32	—	—	—	1,430	1,600	1,750	—	—	—	—	—	2	2	—	4
33	—	—	—	1,540	1,710	—	—	—	—	1	—	2	1	—	4
34	—	—	—	—	1,840	—	—	—	—	1	—	1	—	—	2
35	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Totals	—	—	—	—	—	—	—	161	231	258	264	246	89	21	1,270

¹Date: 1909. Volume table based on actual used and scaled contents of 400 trees. Top diameters of merchantable portions of trees varied from 8 to 20 inches. Stand table based on a total volume of 10,350 board feet per acre, Doyle rule (91). Four years later, Chapman used a "frustum form factor" to construct a similar table for Coosa County, Ala. Except for the taller trees with 4½ or 5 logs, it gave volumes slightly higher than in this table.

per acre, with volumes (Doyle rule) ranging from less than 100 to nearly 2,000 board feet, averaging 350 board feet per tree. The tree of average volume was 19 inches in diameter and contained 3½ logs (Table 57). Such a tree, characteristic of a stand of about 13 M board feet per acre, might be 160 years old (Table 58). Gross yields ran as high as 16 M board feet at 250 years, decreasing after 280 years. However, no deductions were made for decay, which appears at about 100 years and amounts to 20 to 30 percent of the volume of old timber.

Second Growth

The quality and quantity of second-growth yields will depend largely on cultural and utilization practices. Except possibly for a few superior trees, allowed to grow over long periods to meet demands for large or very specialized uses, second-growth trees will never closely resemble old-growth trees because they are too valuable commercially to be permitted so long a period of unmolested development.

Table 58.—*Trees per acre, size of trees, and yields, in pure even-aged stands of old-growth longleaf pine, Tyler County, Tex.*¹ (After Chapman)

Age (years)	Trees per acre	Average diameter breast high	Merchantable height in 16-foot logs	Average tree volume (Doyle rule)	Gross yield per acre (Doyle rule)
	<i>Number</i>	<i>Inches</i>	<i>Number</i>	<i>Board feet</i>	<i>M board feet</i>
100	60	14.0	3	130	8+
110	55	14.9	3 ¼	165	9+
120	50	15.7	3 ½	210	10+
130	46	16.5	3 ½	240	11
140	42	17.3	3 ¾	295	12
150	38	18.1	3 ¾	325	12+
160	35	18.9	3 ¾	372	13
170	32	19.6	3 ¾	413	13+
180	30	20.4	4	491	14
190	28	21.1	4	537	14+
200	26	21.8	4	586	15
210	24	22.5	4	635	15
220	22	23.2	4	688	15
230	20	23.9	4	751	15+
240	19	24.6	4	811	15+
250	18	25.3	4	873	16
260	17	26.0	4	940	16
270	16	26.7	4	1,010	16
280	15	27.3	4	1,073	16—
290	14	27.9	4	1,139	16—
300	13	28.5	4	1,205	15
310	12	29.0	4	1,260	14
320	11	29.5	4	1,310	13

¹Based on timber tallies of 400 acres.

Yields at different ages will vary with the purity and density of the stands. No second-growth longleaf stands have been followed through each successive age class to determine just how density, growth rate, and yields change as time passes. Instead, a theoretical succession of yields at different ages has been set up for fully stocked stands, assuming that the sample representing each age class had always been normally stocked. Fully stocked stands are difficult to find or to recognize when found. Hence the yields shown by so-called normal-yield tables should be accepted only as an indication of possible (not demonstrated) development.

Yield tables for fully stocked stands (Appendix tables IX-a, b, c, d, and e) may be used in various ways in forest management: (1) for selection of suitable rotation periods; (2) for determination of relative productive capacities of ideal stands in the absence of bad fires, hurricanes, or other disasters; (3) for prediction of future yields in volume of wood or piece products (though this is never precise and is not feasible without systematic correction of tabulated values for abnormal stocking); and (4) for appraisal of values such as the present worth of forests, loss in damaged stands, or prospective benefits from forestry measures.

A fully stocked stand of second-growth longleaf pine on a site of average quality is expected to develop as indicated in Table 59. Trees big enough for sawlogs first appear at 25 or 30 years. Thereafter, 3 or 4 additional small pole-sized trees per acre per year should reach 8 inches and 1 or 2 should exceed 10 inches. This "in-growth," together with the increase in size of the larger trees, makes an annual growth of about 1 cord per acre, or 200 to 400 board feet. By the 40th year the yield should

Table 59.—Stocking, growth, and yield per acre in normal, fully stocked, even-aged stands of second-growth longleaf pine on average sites (183)

Age (years)	Trees by diameter classes (inches)—										Annual in- growth by diam- eter classes (inches) 1—		Annual growth		Yield							
	8		10		12		14		16		18		8-18		12-18		Cord- wood (with bark) 4		Saw timber Doyle rule 2		Inter- national ¼-inch rule 3	
	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Num- ber	Cords	Board feet	Cords	Board feet	Cords	Board feet	
15	0	---	---	---	---	---	---	---	---	---	---	---	0	0	0	0.5	0	0	7	0	0	0
20	11	---	---	---	---	---	---	---	---	---	---	---	11	0	0.6	0	0	45	0	15	0	905
25	46	---	---	---	---	---	---	---	---	---	---	---	46	0	1.8	0	0	109	0	22	0	2,715
30	80	14	---	---	---	---	---	---	---	---	---	---	94	0	3.1	0.5	0	166	29	0	4,977	
35	101	24	6	---	---	---	---	---	---	---	---	---	131	6	3.7	0.9	29	220	34	1,000	7,692	
40	117	36	10	---	---	---	---	---	---	---	---	---	163	10	4.1	1.2	50	261	40	2,000	10,407	
45	119	55	18	---	---	---	---	---	---	---	---	---	192	18	4.3	1.6	67	291	44	3,000	13,122	
50	120	65	21	---	---	---	---	---	---	---	---	---	206	21	4.1	1.7	100	335	49	5,000	16,742	
55	113	67	30	8	---	---	---	---	---	---	---	---	218	38	4.0	1.9	118	354	53	6,500	19,457	
60	106	73	35	11	---	---	---	---	---	---	---	---	225	46	3.8	2.0	125	369	56	7,500	22,172	
65	93	74	39	13	3	---	---	---	---	---	---	---	222	55	3.4	2.0	138	376	60	9,000	24,435	
70	81	76	42	18	3	---	---	---	---	---	---	---	220	63	3.1	2.0	143	388	64	10,000	27,150	
75	73	74	45	19	6	---	---	---	---	---	---	---	217	70	2.9	1.9	153	386	67	11,500	28,960	
80	64	70	48	24	8	---	---	---	---	---	---	---	214	80	2.7	1.9	162	390	69	13,000	31,222	
85	55	66	50	28	10	---	---	---	---	---	---	---	209	88	2.5	1.8	171	388	72	14,500	33,032	
90	51	63	50	29	15	---	---	---	---	---	---	---	208	94	2.3	1.7	178	387	74	16,000	34,842	
95	44	58	51	33	14	2	---	---	---	---	---	---	202	100	2.1	1.7	184	381	76	17,500	36,200	
100	36	55	51	36	16	4	---	---	---	---	---	---	198	107	2.0	1.6	185	376	78	18,500	37,557	

¹Annual in-growth as shown here is the number of trees reaching the 8- or 10-inch d.b.h. class each year.

²All trees 8.6 inches d.b.h. and up, to a top diameter 7 inches inside bark.

³All trees 6.6 inches d.b.h. and up, to a top diameter 5 inches inside bark.

⁴All trees 3.6 inches d.b.h. and up, to a top diameter 3 inches inside bark.

equal 40 cords, or from 2 to 12 M board feet per acre, depending on the log scale and utilization limits.

Comparison of Virgin and Second Growth

To the extent that full stocking is attainable, the denser stands of second growth will yield appreciably more wood per acre but less per tree than virgin stands.

When trees are used for lumber only, the manufacturing waste will be somewhat greater than in other uses. Nearly 7 board feet can be sawed from each cubic foot of virgin timber, mainly because logs are large. About 6 are cut in second growth, or if the total stem volume including the conical unused top is computed (Fig. 69), only 4½ or 5 board feet per cubic foot. The used portion of a tree is more nearly cylindrical (i.e., tapers less) in virgin than in second growth, thus accounting for superior volume.

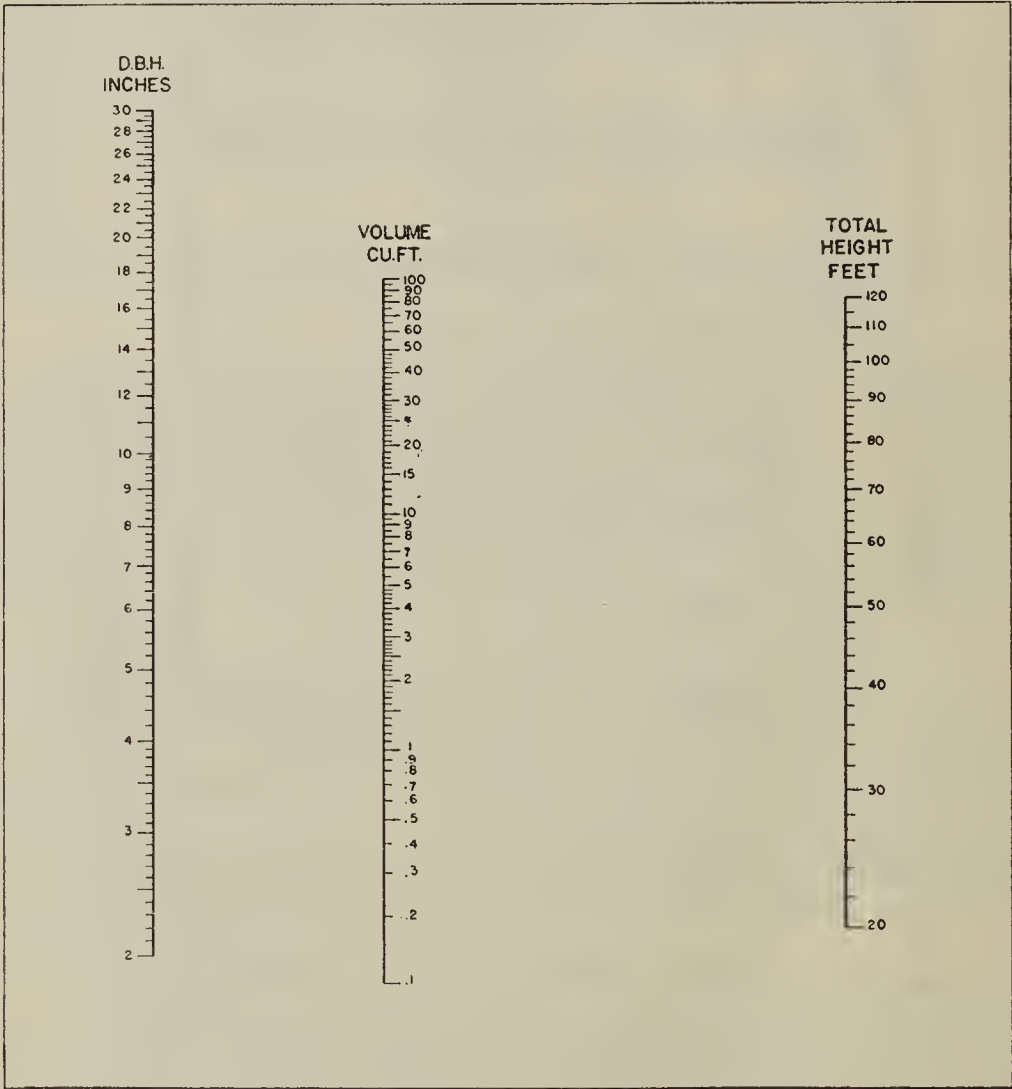


Figure 69.—Alinement chart showing volume of entire stem (ground surface to terminal bud) in cubic feet inside bark as related to d.b.h. and height of second-growth longleaf pine. Basis: 493 trees on the Coastal Plain from South Carolina to Texas; computation of Smalian's formula by logarithmic multiple-regression equation, with a standard error of 5.95 percent. (After Chapman)

Second-growth trees scale only three-fourths (Doyle rule) and four-fifths (International $\frac{1}{8}$ -inch rule) as much as virgin trees of comparable heights and diameters. Trees typical of two prevalent sizes—a 14-inch, 65-foot, 3-log tree and a 16-inch, 85-foot, 4-log tree (Table 57 and Appendix Table VIII-a)—illustrate this difference. By the Doyle rule the 3-log tree scaled 130 board feet virgin or 98 board feet second growth; by the International rule, 202 board feet virgin or 158 board feet second growth. By the Doyle rule, the 4-log tree scaled 255 board feet virgin or 188 board feet second growth; by the International rule, 346 board feet virgin or 293 board feet second growth.

In virgin stands at 100 years, 14-inch trees were most abundant, while in second growth 80 to 100 years old the 10-inch size is prevalent (Tables 57 and 59).

It is probable that the second-growth longleaf stands used in the study from

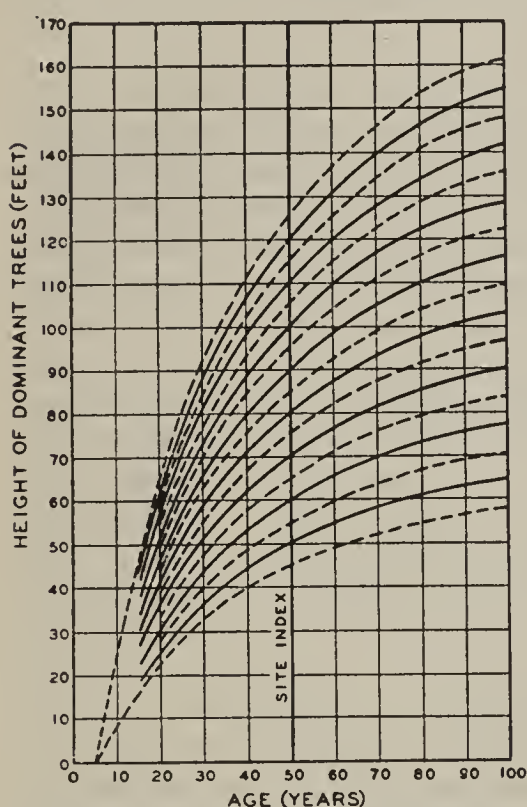


Figure 70.—Site-index curves for classifying the quality of longleaf pine sites (After Bruce)

which the above figures were derived were not fully stocked in their early years, and hence developed more rapidly than those in which trees were crowded from the start. On the other hand, early crowding undoubtedly pruned the stems and contributed quality to many a virgin stand that became relatively open at maturity. Whether or not the indicated high rate of production can be maintained in fully stocked stands is problematical. It may not be possible or desirable to maintain stand densities close to the theoretical normals. Thus, although many neglected virgin stands accumulated 16 M board feet in 250 years, we do *not* know that managed second-growth stands can actually produce about as much volume in less than half the time—that is, about 18.5 M board feet in 100 years (Table 59), although under management, wood removed in intermediate cuts will greatly augment final yields.

The usual basis for classifying the quality of timber-producing sites is the height of dominant and codominant trees at 50 years, the corresponding heights for other ages being indicated by harmonized curves (Fig. 70).

Appendix Tables IX-a, b, c, d, and e show normal yields by 5-year periods for site indices of from 40 to 110 feet.⁸

⁸For the eastern part of the longleaf range, particularly in flatwoods regions underlain by hardpan, precautions are needed in using these site-index curves. Here height-growth curves flatten off at an earlier age, and corresponding differences in volume yields have not been determined. The curves fail to indicate site quality correctly in very young or very old timber, and on very good or very poor sites, because of the method by which they were constructed.

DETERMINATION OF VOLUME AND GROWTH

Using any given log rule or unit of volume in measuring any species of timber, the results vary mainly with stem form and degree of utilization. Hence, before applying any existing volume table, it should be examined to determine its fitness for local use.

Girard (215) has shown how cruising methods developed in ponderosa pine stands can be applied to longleaf and other yellow pines. Among the characteristics common to this group are the limits of utilization of ordinary virgin stands. Girard found that the upper (or small end) diameter of the used portion of a tree averaged about 50 percent of the d.b.h. measurement, regardless of the species of yellow pine or its location.

Volume

In estimating volumes of virgin longleaf pine timber, Girard found the following ratio useful to timber cruisers: diameter inside bark at the small end of an average 16-foot log is 70 percent of the diameter outside the bark at breast height. This formula seemed to be widely applicable to longleaf pine trees. Girard also reported that the ratio varied from 66 to 72 percent of breast-high diameter for any southern pine, virgin or second growth, where top diameters ranged between 40 and 60 percent of diameter at breast height and averaged about 50 percent.

For longleaf and other southern pines, a set of volume tables showing board-foot contents by the Scribner log rule⁹ are available, showing diameters, merchantable lengths (in logs from 1½ to 5) and taper (339). Taper is defined here as the difference in inches between diameters outside bark at breast height and inside bark at merchantable height. To use these tables, an estimate of taper for each breast-high diameter class must be made in the field. While there is as yet no uniformly accepted numerical expression of stem form, the use of volume tables based on some index of taper is increasing.

The Girard form factor (ratio of inside-bark diameter at the top of the first 16-foot log to outside bark diameter at breast height) is now widely used (Table 60) (564). Because taper differs from place to place, there will be variations between true tree volumes and volume-table values. Such discrepancies make it inadvisable to use volume tables without first testing their local application.

Growth

Because longleaf grows in relatively pure even-aged stands, its development may be forecast on the basis of normal-yield tables, but a more reliable method is to use only data from the tract in question. The expense of a 100-percent survey of an entire forest is sometimes justified, but more often it is sufficient to cruise selected portions of the forest, using enough random plots or lines to permit an estimate of sampling errors. Where recent aerial mosaics are available, the ground work may be confined to representative transects that can be definitely located on the photo-

⁹The Scribner log rule is more accurate than the Doyle rule generally used in the South. The Scribner Decimal C log rule has long been the official rule used by the U. S. Forest Service.

Table 60.—Average stem taper, upper diameter, and volume of old-growth longleaf pine of 3 size classes¹
(After Girard and Gevorkiantz)

Merchantable height by 16-foot sawlogs (number)	Diameter at breast height (inches)—								
	14	20	26	14	20	26	14	20	26
	Taper of stem			Upper diameter			Volume (Scribner rule)		
	Inches	Inches	Inches	Inches	Inches	Inches	Bd. ft.	Bd. ft.	Bd. ft.
1	---	---	---	11.9	16.6	21.7	84	180	325
2	1.4	1.7	2.0	10.5	14.9	19.7	146	322	588
3	1.7	2.1	2.3	8.8	12.8	17.4	186	422	788
4	2.0	2.4	2.5	6.8	10.4	14.9	205	483	930
5	---	3.0	3.0	---	7.4	11.9	---	507	1,014
Average	---	---	---	8.0	10.3	13.2	---	---	---

¹Based on 127 Louisiana trees. The 14-inch group included trees from diameter classes 12 to 16 inches inclusive; the 20-inch group included classes 18 to 22; and the 26-inch group, classes 24 to 28. The diameter inside bark at the top of the first 16-foot log expressed as a percentage of the diameter outside bark at breast height varied from 83 to 85 percent. The upper diameters show utilization limits inside bark at the small end of the top log.

graphs. By this method two or more stand-density classes can be readily recognized, delimited on the map, and sampled in the field survey. This method of segregating the more heavily timbered areas, where diameter growth is less rapid, facilitates intensive sampling of the better stands. Because of the rapid development of even-aged sapling stands, separate records of in-growth are advisable. Where increment in volume is sought only for the forest as a whole, a simple method of projecting stand tables into the future is adequate, provided that allowance is made for existing trends in average rates of diameter growth. Failure to take into account possible deceleration in diameter growth in uncut stands, or of acceleration in heavily cut stands, can be a source of large error (388, 585).

Prediction of timber growth by projecting stand tables is not always necessary after conservative cutting practices have become stabilized. For properties already under some form of forest management, the recurring-inventory method is a suitable means of determining current growth and regulating the cut (585).

SUMMARY

The original longleaf pine forests were made up mainly of pure, even-aged, irregularly open stands. The purity and openness of the virgin forest is ascribed to the occurrence of frequent fires and the high fire tolerance of this species. The even-aged character was the result of relatively infrequent but heavy seed falls and the ability of reproduction to survive only in openings free of an overstory.

Virgin stands grew slowly and produced close-grained timber of high grade. Somewhat lower grades are produced by the more rapid-growing second growth. This is particularly true of old-field stands, where heavy yields of relatively knotty lumber culminate early. Steady and sustained production of medium grades at moderate rates is preferable.

Pines that continue their growth well into the summer produce dense wood. This late seasonal growth is measurably affected by both air temperature and soil moisture, extreme summer heat being associated with relatively early cessation of growth, and

moist soil being associated with a more prolonged formation of summerwood. Diameter, height, and volume growth are reduced about 20 to 40 percent while a tree is being turpentineed.

When crowded longleaf pines are freed from neighboring competitors, growth rate increases in two or three years on the poorer sites, and immediately on the better sites, the response depending in some measure on the size and vigor of the crowns. On better sites the producing power of even badly suppressed individuals is restored. Response of small trees to liberation may be spectacular in terms of board feet; the larger and heavier crowned trees show smaller increases because of previous growth at more nearly full capacity. Natural limits are placed on these increases as the growing trees compete with one another and growth rates become stabilized. The maintenance of fairly constant diameter growth helps to provide uniformity in the quality of wood produced.

As a timber tree, longleaf pine has much in common with other southern pines and with hard or yellow pines in general. Hence, certain rules of thumb can be applied to all these species in estimating timber volume. As in most yellow pines, the diameter at the top of the merchantable stem in longleaf is roughly half that at breast height. Seventy percent of the diameter at breast height, outside bark, of the tree of average volume in a stand closely approximates the small end or scaling diameter of a log of average volume in this tree.

Because some of the finer specimens of longleaf may be permitted to grow as "standards" over extended periods—possibly two rotations—the capacity for satisfactory, sustained development of roots, crowns, and stems is of practical importance. The normally long, stout taproot makes the larger trees exceedingly wind-firm. The usually adequate vertical penetration of roots is limited by a hardpan layer on certain sites. Effective lateral spread of roots is curtailed in well-stocked stands prior to the closing of the crowns. With some roots spreading out to 50 feet or more, the larger trees are capable of utilizing the soil to an average radius of 30 feet. Less space may retard stem growth and modify stem form.

Merchantable longleaf pines in any given diameter and height class contain more wood in old-growth than in second-growth stems. The taper of trees in undisturbed stands tends to decrease progressively, that is, the merchantable portion becomes more nearly cylindrical as trees grow older. Rapid growth in widely spaced stands is obtained at some sacrifice of the desirable full-boled form typical of virgin timber.

Normal-yield tables are recognized as applicable in a limited way for judging maximum production in unmanaged stands. They provide a reasonable conception of numbers and sizes of trees compatible with certain age and site classes, or, together with empirical data, a measure of discrepancies between understocked and fully stocked stands. Thus, they serve to gage potential development. Prediction of growth rates in the early stages of management, however, is best done by projecting stand tables. For determining growth and control of growing stock in forest management, the recurring inventory is suitable.

XII. Management of Longleaf Pine Forests

OBJECTIVE AND DEVELOPMENT OF FOREST MANAGEMENT

THE objective of forest management is a sustained yield of timber products in sufficient quantity and adequate quality to yield a reasonable margin of return over costs. New markets are developing in the South, and the integrated production of a variety of wood products is becoming more profitable. The ultimate object of most private forest management will probably be to develop intensive practices that will sustain the highest financial return per acre per year.

Effective forest management should comprise the following steps: (1) an appraisal of the feasibility of practicing forestry on the available lands, and an estimate of the probable returns from certain products; (2) the employment of a professional forester; (3) the formulation of a forest policy and plan covering protection, cultural practices, harvest cuttings, and regeneration; and (4) the development of an organization to administer the various phases of the plan.

It is advisable to avoid making detailed plans until policies have been thoroughly crystallized. Many problems should receive careful preliminary consideration, such as (1) major commodities to be produced; (2) markets to be supplied; (3) degree of fire protection and use of controlled burning; (4) turpentine and timber cutting—whether to be done by the owner or by lease of faces and sale of stumpage; (5) disposal of worked-out trees; (6) reforestation methods—whether natural or artificial; and (7) practicability of thinnings and other cultural operations. When decisions have been made on these matters, detailed action can be taken.

In the past, the first step in organizing the management of a block of forest land was usually a cruise or inventory of the timber and other forest resources. Intensive cruises made available data on the number of trees by species and diameter at breast height, average rate of diameter growth for each species and diameter class, number and size of trees being worked for naval stores, height of faces, and number and size of worked-out trees. A map was usually made to show boundary lines of the tract, landownership, fire lanes, roads, highways, railroads, streams, swamps, treeless patches and areas in recognized types of forest, turpentine crops, young growth, and reproduction.

It is now generally recognized that not all this information (though useful) is essential for good management. Furthermore, it is not always worth the cost of collection. Silvicultural practices can be introduced without complete data on forest volume, stand composition, and rates of growth. In fact, the gathering of such data can be advantageously postponed until the first improvement cuttings have removed the bulk of inferior growing stocks. Growth and yield data can then be obtained

as part of the process of keeping current records of progress in turpentine and in marking and cutting timber. This economical procedure, known as the continuous or recurring inventory, provides much information essential to balancing forest growth against forest drain. The necessary data can be accumulated gradually as a part of the regular operation of the business of producing gum and timber.

The simplest way to handle an extensive forest property is to produce and sell stumpage only and to lease special rights. If it can be done efficiently, however, it is usually more profitable for an owner to do his own turpentine and logging. On large properties the extraction of each product can be handled advantageously by separate crews. For example, when a crop of timber has been worked out for turpentine, it may be turned over to the pole and pile department. After these commodities have been harvested, portable tractor-type mills may be brought in to remove designated saw-timber trees. The area can then be cut over for pulpwood. Stumps and lightwood may be removed at any time for manufacture into wood naval stores. Supplementary income from game or grazing should also be considered.

On the whole, successful management depends largely on a diverse utilization of the forest's products, and this greatly facilitates the improvement of forest stands. The production of a single class of products is not recommended, although one class should usually be the primary objective. Management, however, should be flexible enough to shift from one product to another as market demands change.

FOREST-MANAGEMENT OPPORTUNITIES

Timber growing can be profitable in the South, because of certain natural and economic advantages, such as relatively cheap land forested with promising second growth, a warm and humid climate, long growing season, and accessibility to diverse and expanding markets for wood products. In the longleaf pine belt, progressive forestry is most evident in the better locations, particularly in the Southeast, where slash pine is a valuable associate. Soils are more favorable for tree growth in the western part of the belt, but timber stocking and markets are more favorable at present in the eastern portion.

There is more true forest land and relatively fewer good farms in the longleaf belt, especially in the eastern part, than in the rest of the southern pine region. The farms in the longleaf belt, on the average, contain a greater acreage of woodland than farms in other parts of the South. Moreover, the potential income from woodland is relatively high because trees may be first worked for naval stores and later sold for saw timber, ties, pulpwood, poles, or piles.

Logging is relatively easy on the flat terrain of the longleaf region. The use of trucks permits economic harvesting of isolated trees or patches of timber which formerly had to be left in the woods. Most of the timber is readily accessible throughout the year, although trucks cannot enter some sites in very wet weather.

With good markets available, many small, dense-grained longleaf trees can be logged profitably for special uses, although they may be unprofitable as lumber because of low grades, narrow widths, or high logging costs. Such trees, as will be shown, can be economically retained for seed and growing stock. Their value for

these purposes has been commonly underestimated and their value as sawlogs overestimated.

In the naval stores region, growing stocks can be materially increased through proper management. The number of trees available for turpentine could be raised from 25 or 30 to at least 90 and possibly 150 or more per acre on the better sites, and average yields of about 30 or 40 units per crop increased to about 60 units. As growing stocks are built up to make full use of every acre, productive trees will be more concentrated and a turpentine crop will cover but a small portion of its present area. Concentration will expedite woods work and lower the costs of supervision.

According to Phillips (456), the requisites for business success in turpentine farm management are: (1) sufficient capital, (2) adequate timber at reasonable lease prices, (3) economic production of maximum yields, (4) proper marketing, (5) freedom from the devastating effects of drought, storm, and destructive competition, (6) proper selection of trees to obtain maximum yields per cup, and (7) a supply of efficient labor. In addition, of course, freedom from serious fire damage is necessary.

Until recent years, the gum naval stores industry has been backward in discarding inefficient equipment and procedures, as illustrated by the continued use of fire stills and inadequate packing, storing, and distributing methods. In the past 10 years, however, several centralized gum-distilling plants were built, most of them in southern Georgia. The number of fire stills dropped from over 1,100 in 1934 to less than 500 in 1943. In 1944 the centralized distilling plants handled over half the total output of gum, thus bringing to gum farmers substantial savings in transportation, processing, inspection, commissions, storage, and insurance. Furthermore, the traditional dominance of the industry by "factors" is declining as producer-processors increase. The factors no longer finance and control the industry as a whole.

Owners of longleaf pine timber should also profit from the increase in pulp and paper mills in the South. Pine wood in sizes and forms that once were seldom merchantable now find ready markets. Indeed, except for some regions that are relatively inaccessible, pulpwood markets are now available to most owners of longleaf pine.

Forest Subdivision and Stand Classification

For administrative purposes, large forests may be divided into blocks, working circles, and ranger districts. These may be subdivided into compartments or administrative units of convenient size or distinctive condition, bounded by natural features or artificial lines. The larger compartments may include several stand conditions that should be recognized and classified on the basis of two or more of the following characteristics with subclasses as needed:

1. *Commercial status*.—Merchantable and unmerchantable stands, or operable and nonoperable portions of a forest.
2. *Silvical origin*.—Virgin, second-growth, planted, and old-field stands; natural reproduction; unreproduced, etc.
3. *Forest type*.—Various species or mixtures of species to be recognized in management.

4. *Form*.—Many-aged or even-aged; if even-aged, either single-canopied or two-storied.

5. *Density*.—Full (75 to 100 percent of normal), medium (25 to 75 percent), or light (0 to 25 percent).

6. *Site quality*.—Based on soil fertility or site index.

7. *Tree size*.—Seedlings; saplings; small timber, including poles, but usually no trees over 13 inches d.b.h.; medium timber, between 13 and 21 inches d.b.h.; and large timber, over 21 inches d.b.h. The stage of maturity is roughly indicated by these classes, and they can be substituted for the broad age classes so often used in early forest-working plans.

8. *Treatment needed*.—Areas for which controlled burning, planting, turpentine, and various types of cultural and harvest-cutting operations are needed.

Most of the above stand conditions as well as forest types are best shown on maps which are useful in planning appropriate treatments and recording their progress on areas larger than a small or homogeneous woodlot or a single forest compartment.

TIMBER-STAND IMPROVEMENT

Fully stocked stands or those with a complete crown canopy generally yield the following benefits: (1) the site is fully utilized; (2) natural pruning is facilitated and a large proportion of high-grade lumber is produced; (3) surface fires burn slowly because there is little grass and wind velocity is reduced; and (4) regeneration can follow harvest cuttings owing to the fact that seeds are not hung up in grass. If young stands are left too long in a fully stocked or overstocked condition, however, the growth rate of crop trees is seriously retarded. The more uniform the trees in a stand with respect to height and crown development, the greater the reduction in growth.

Thinning of Pure, Even-Aged Stands

Longleaf is outstanding among southern pines in its expression of dominance. The development of longleaf, therefore, suffers less than that of other southern pines in dense, unthinned stands. It is difficult to find even small patches of young growth so dense and uniform that noncommercial thinning is needed to insure satisfactory development. Natural thinning is usually sufficient in the seedling and sapling stages, except perhaps where wide spacing is desired for naval stores production.

When stands reach the stage at which merchantable trees die from crowding and suppression, natural thinning is obviously wasteful. At this stage also—if not earlier—the growth rate of even the better trees is appreciably reduced by intense competition. Waste of merchantable volume and reduction in growth of crop trees can be avoided by artificial thinning operations. This prevents loss of trees from mortality and at the same time provides more growing space for selected crop trees.

Thinnings are rarely needed in longleaf pine stands until the trees selected for removal are large enough to pay for the operation. One company in the naval stores region spent 56 cents an acre in 1935 to thin stands that had only one-third

normal stocking. Such thinnings, which removed mostly suppressed trees less than 6 inches d.b.h., leaving about 275 stems per acre, were unnecessary and ineffective.

Thinnings are generally advisable in crowded stands, however, when the trees selected for removal are of pulpwood size and most of the best trees have shed their lower branches for at least 1 and possibly 2 log lengths. If sawlogs are the main product desired, thinnings should be deferred until the limbs are dead up to about 25 feet, and preferably more, provided the crowns of crop trees have not been excessively reduced by this time.

The frequency and severity of thinning depend on the degree of crowding as well as the products desired and markets for trees to be cut. (The expanding demand for pulpwood, as noted, offers a good market for thinnings.) Thinnings should be made in such a way and with such frequency that the full productive capacity of the site will be utilized. If they are too heavy or premature, the volume and quality of subsequent growth will be sacrificed. Under these conditions the trees will develop very wide crowns, and clear lengths will be short. On the other hand, if thinnings are too late or too light, the crowns of remaining trees will be too narrow and thin for rapid recovery. Maximum volume growth (and probably maximum value) per acre is apparently obtained when thinnings maintain a crown length on final crop trees equivalent to 33 to 40 percent of total height. Wherever possible, stands should be thinned frequently, preferably at intervals of 3 to 10 years.

Dense stands should be thinned largely from below because of the marked inferiority of trees that have long been subdominant. Enough dominant and codominant trees should be removed to open the main crown canopy. Trees unmerchantable merely because they are small should be retained if they do not interfere with the crowns of crop trees. Overtopped trees should usually be left if they are not merchantable (or barely so) as they have little effect on the growth of other trees and may later have an opportunity to grow and become much larger. Even in dense stands there are some wide-crowned trees that should be removed early, such as the rough-stemmed dominants so prevalent in old-field stands. Irrespective of crown class, individuals that badly crowd crop trees should be cut. It is essential to make numerous openings in the main crown canopy if the thinning is to increase the growth rate of remaining trees materially.

Mitchell (395) says that for the central hardwood-southern pine region desirable spacing in feet for trees should be approximately equal to the average d.b.h. in inches, plus 6. This "D plus 6" rule seems to be workable in longleaf pine at least in 4- to 10-inch diameter classes, and perhaps over a much wider range of sizes. Thus, 4-inch trees should be 10 feet apart, permitting a total of 436 trees per acre in a uniformly stocked stand. More growing space is needed if the trees are to be turpentine than if they are to produce mainly sawlogs, poles, piles, and pulpwood.

The extent to which suitable thinnings increase the growth rate of crop trees over that attained in unthinned stands is uncertain, and obviously depends on many factors. Apparently, the increase for longleaf is comparable to that obtained in other southern pines, allowing for the fact that longleaf usually does not suffer from lack

of thinning as soon as do the other species. The total volume of material obtained from frequent thinnings in well-stocked stands of longleaf pine, up to 50 to 70 years of age, probably equals at least one-third the total yield during the life of the stand.

Thinning operations in 30- to 40-year old longleaf and slash pine second growth can pay carrying charges on the investment in land and timber, including 4 percent simple interest annually. The following computation shows the costs and returns per acre from thinning over a period of 13 years on a tract acquired in southern Georgia in 1926:

Interest on cost of land, \$3 carried at 4 percent.....	\$1.56
Interest on cost of timber, \$4 carried at 4 percent.....	2.08
Taxes and administration at 15 cents per annum.....	1.95
Total outlay	\$5.59
 Gross return from thinning in 13 years.....	 \$14.00
Total outlay in 13 years.....	5.59
 Net return in 13 years.....	 \$8.41
Average annual return.....	0.65

These thinnings were carried out by permanent woods crews, employed for maintenance of roads and telephone lines and fire protection, and hence cost nothing over and above these current administrative costs. Thinnings yielded approximately 10 cords of pulpwood per acre in the 13 years. About 200 choice, well-spaced trees were left per acre for subsequent crops of turpentine, sawlogs, and pulpwood.

Other Stand-Improvement Cuttings

On many former longleaf pine sites loblolly and shortleaf have recognized commercial value, but are not always desirable associates. Too often the associated pines are able to obtain a five-year start in regeneration without completely capturing the site, and suppress the longleaf while developing into bushy wolf trees. To prevent this, such pines should be removed in the seedling stage by the use of fire, or in the sapling stage by cutting. Slash pine usually has good form and quality, and, being a valuable source of turpentine, is generally a desirable associate.

The principal undesirable hardwood associates, as already observed, are oaks—mainly blackjack, bluejack, post, southern red and turkey oaks. Commercially useless in most cases except for fuel, these “scrub oaks” are true forest weeds in the longleaf type (Pl. 11, B). Sprouting vigorously and persistently following cutting or fire, they may not only suppress longleaf seedlings and saplings but spread rust-canker disease to the pines. Scrub oaks and other undesirable hardwoods should be removed by weeding or liberation cuttings.

Weeding is advisable in much natural second growth. The nearly pure pine stands on old fields, however, do not need such treatment. Eradication of hardwoods requires drastic measures such as cutting, burning, girdling, poisoning, or shearing and mangling with some heavy power-driven machine such as a bulldozer. Trees 10 inches in diameter or larger may be killed simply by girdling or cutting, but smaller hardwoods usually sprout profusely and the only single treatment so far found generally effective, without repetition, is the application of sodium arsenite. Five gallons

of this poison may be prepared by mixing 40 pounds of dry white arsenic with 10 pounds of caustic soda flakes (lye), gradually stirring in 15 quarts of water. Mixing should be done outdoors, because the fumes are toxic. Pessin (450) recommends the application of this solution in summer, in holes 1 or 2 inches deep and $\frac{1}{2}$ inch wide at the base of the trunk, or in adjacent roots of the tree. Such holes can be made with an ordinary brace and bit, or more readily with a special punch (Fig. 71). The forests should be closed to grazing animals while the poison is being applied and until it has been completely absorbed by the trees.

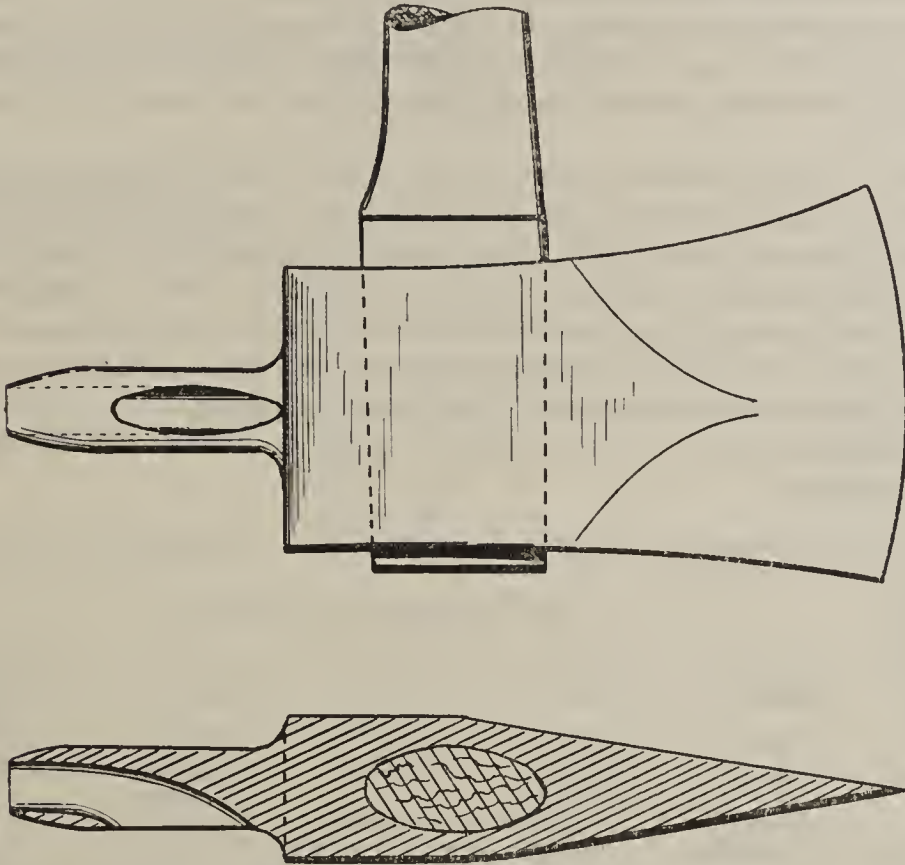


Figure 71.—Side and sectional top view of hole-punching tool. Mounted on an ax, this punch makes cylindrical holes in the base of the tree to be filled with liquid poison. (After Pessin)

Control of worthless, aggressive vegetation has also been accomplished experimentally by burning, or by release cutting and burning, but detailed recommendations have not been worked out. The larger the weed trees, the less susceptible they are to control by fire alone. Scrub oak thickets sometimes can be set back by mangling. Mechanical tractor-drawn brush cutters with special guards to protect men operating in rough woodlands have been used in the longleaf pine belt, especially in game preserves (536). These devices weigh about 3,300 pounds and employ heavy cylinders in which steel fins are set horizontally as cutting blades. When their rough-shod rollers are drawn through a tangle of vegetation, they knock down shrubs and saplings and cut tops and surface roots. As a result, mineral soil is exposed to

any vegetation that can take over the site. Cutting of preliminary trial lanes is useful to indicate what vegetation may be expected to follow such radical treatment.

Sometimes the products resulting from weeding operations can be sold. For example, a brick kiln in southern Alabama uses all common species of wood as fuel. More than four-fifths of its fuel consists of scrub oaks, inferior swamp hardwoods, titi, slabs from nearby portable mills, lightwood, turpentine jump-butts, tops, and other residue from logging operations. This market has enabled nearby farmers to pay for the clearing or weeding of forest stands. On one farm it cost \$8 per acre to clear the land in 1942, with returns of \$10 plus a winter's fuel supply. In another instance, where scrub oak stumpage brought 50 cents a cord, the net income from clearing was \$8.54 per acre. Similarly, because of the market provided by the kiln, a local timber stand-improvement cutting showed a profit of from \$2 to \$5 per acre (50).

Timber stand-improvement cuttings made by the Civilian Conservation Corps in the longleaf-slash pine type and in the longleaf pine-scrub oak type were adapted to different classes of stands (566). These were distinguished on the basis of forest type, form, and density of stocking. The main conditions were: (1) single-storied, sparsely stocked stands; (2) two-storied stands with dense overstory and sparse understory; (3) two-storied stands with sparse overstory and dense understory; and (4) two-storied stands with sparse overstory and sparse understory.

For single-storied, even-canopied stands, a guide to desirable spacing similar to Table 61 was used.

Table 61.—*Classification of stocking in second-growth stands in the longleaf-slash pine type*¹

Average diameter breast high (inches)	Trees per 1/10-acre unit (number)—				
	10	20	30	40	50 and over
0-2	Sparse	Sparse	Sparse	Sparse	Desirable to overdense
3-5	do.	do.	do.	Desirable	do.
6-8	do.	Sparse to desirable	Desirable	Desirable to overdense	Overdense
9 and over	Sparse to desirable	Desirable to overdense	Overdense	Overdense	do.

¹Adapted from Stand Improvement Measures for Southern Forests (566), assuming that the object of management is to integrate the production of gum, poles, piles, sawlogs, and pulpwood.

Stand-improvement cuttings should remove trees which encroach on better individuals. Wolf trees are easily recognized. These and others of low present or potential values should be cut early. Poorly formed or defective trees of valuable species may be cut to encourage the growth of well-formed and sound trees of a species in less active commercial demand. Occasionally, some understory trees like dogwood, salable only for highly specialized uses, should be favored. The potential development of trees and relative market values of their products must be known to timber markers. Only in this way can species and stem character receive the joint consideration necessary in a stand-improvement operation.

The following classification of species found in two of the longleaf pine types should be useful in planning the improvement of growing stocks:

FOREST TYPE AND SPECIES VALUE

SCIENTIFIC NAME

Longleaf-slash pine:

Longleaf slash pine:			
Valuable commercially -----	{	Pine, longleaf	<i>Pinus palustris</i>
		Pine, slash	<i>P. caribaea</i>
		Pine, loblolly	<i>P. taeda</i>
		Cypress, pond (Pondcypress)	<i>Taxodium ascendens</i>
		Gum, swamp black (Swamp tupelo; blackgum)	<i>Nyssa sylvatica biflora</i>
Occasionally merchantable -----	{	Pine, pond	<i>Pinus rigida serotina</i>
		Pine, sand	<i>P. clausa</i>
		Oak, southern red	<i>Quercus falcata</i>
		Oak, post	<i>Q. stellata</i>
		Dogwood, flowering (for small blocks and bolts)	<i>Cornus florida</i>
Seldom or never reaching sawlog size -----	{	Maple, red	<i>Acer rubrum</i>
		Oak, blackjack	<i>Quercus marilandica</i>
		Oak, bluejack	<i>Q. cinerea</i>
		Oak, sand live	<i>Q. virginiana geminata</i>
Longleaf pine-scrub oak: ¹			
Valuable commercially -----		Pine, longleaf	<i>Pinus palustris</i>
Occasionally merchantable -----	{	Pine, sand	<i>P. clausa</i>
		Oak, southern red	<i>Quercus falcata</i>
Seldom or never reaching sawlog size -----	{	Dogwood, flowering	<i>Cornus florida</i>
		Gum, black (Black tupelo; blackgum)	<i>Nyssa sylvatica</i>
		Hophornbeam, eastern	<i>Ostrya virginiana</i>
		Hickory, mockernut	<i>Carya tomentosa</i>
		Hickory, pignut	<i>Carya glabra</i>
		Oak, blackjack	<i>Quercus marilandica</i>
		Oak, bluejack	<i>Q. cinerea</i>
		Oak, sand live	<i>Q. virginiana geminata</i>
		Oak, post	<i>Q. stellata</i>
		Oak, turkey	<i>Q. laevis</i>
		Persimmon	<i>Diospyros virginiana</i>

¹The oak species listed here occur in this type principally in scrub form.

Trees should be selected with a view to reserving mainly those which are sound and have space to grow profitably. Some inferior trees may be left to avoid opening the canopy too much before regeneration is desired. As the crowns again fill out, subsequent improvement cuttings can gradually remove inferior trees left in early cuttings—stunted and hopelessly suppressed trees; tall spindling trees with little top; injured trees, including those worked out for turpentine; diseased trees; and trees with serious wounds or cat faces at the base.

PRUNING

Longleaf prunes itself better than other southern pines except slash. In well-stocked stands crowding is the main cause of natural pruning, but fire and perhaps insects are contributory causes. An insect, *Pityoborus comatus* Zimm., that occasionally breeds in lower living branches of longleaf weakened by shading, may occasionally assist in the pruning process (41). The heat killing of foliage as a result of fire often hastens the death of lower limbs of saplings. Promiscuous burning during the regeneration period, however, may reduce the density of seedling stands so that the survivors become relatively open grown, limby, and of low value unless artificially pruned.

Paul (427) found that shaded lateral branches of longleaf pine die when they are 7 to 9 years old, and some 5 to 15 years later decay and fall to the ground. The total number of branches, and hence the number of knots in the trunk, obviously depends on the number of limbs per node and the distance between nodes. This suggests that the relative freedom from knots in southern pine may be attributed to the rapid growth of the trees. Paul points out, however, that not only is the rate of height growth independent of the number of branches per whorl, but that branches develop at points intermediate along the season's growth, indicating that other factors are at work. It is significant that, in the first 20 feet of trunk, southern pines seldom have five and usually only two to four branches per node; and that these do not remain on southern as long as on northern pines. In respect to natural pruning, longleaf leads the pine species studied by Paul (Table 62).

Table 62.—*Dead branches and knots in pine* (After Paul)¹

Item	Longleaf	Slash	Loblolly	Shortleaf	Red	Northern white
Knots in first 20 feet above stump.....number	37	50	70	110	75	85
Longevity of branches producing ingrown knots years	7	9	7	8	15	15
Persistence of dead branches producing loose knots:						
Average period observed.....do.	6	6	8	12	23	27
Maximum period observed.....do.	17	20	49	41	---	---

¹The data for longleaf pine are based on 15 trees: 5 from each of 3 second-growth stands, one stand in Florida and the other two in Mississippi. The trees were 5 to 11 inches d.b.h., 46 to 72 feet high, 20 to 30 years old, and numbered 350 to 530 per acre (427).

In range of thickness and average total length of knots, longleaf is much like the other southern pines except loblolly, whose knots are somewhat longer. The superiority of longleaf over other species of pine is not as complete as Table 62 indicates, however, since Paul found that the average diameter of longleaf knots (about 0.6 inch) was a trifle larger than that in any other pine studied, and that the average length of the live portion of large knots was greater than that in other southern pines. Knots in southern pine, incidentally, averaged 2 to 3 inches in length compared with 3 to 4 inches in northern white and red pines. Dense stands of second-growth longleaf usually have smaller knots than do virgin stands.

Longleaf pines are relatively intolerant of shade and this partially explains the high proportion of clear lumber produced. As Paul (427) says: "Under equal forest conditions, branches on tolerant species remain green longer and produce larger intergrown, or 'live,' knots than do branches on intolerant species." On the other hand, there is no relationship between tolerance and the persistence of dead branches. Even in the South, with its long humid summers, some small branches may persist for 50 years because they dry too quickly to permit decay. In a mixed forest, the heavy shade of broadleaved species maintains a high moisture content in dead branches, and thus promotes decay and early shedding of the branches of associated pines.

The abundance of clear wood in virgin forests was due largely to early suppression and the advanced age and large size of the trees. As the scarcity of high-quality timber in the midst of an abundance of low-grade wood becomes more acute, the need for—and profits from—artificial pruning will increase.

In the more open stands of longleaf saplings, artificial pruning sometimes may be necessary to provide clear wood for turpentine faces and permit the early production of select grades of lumber. Even when well-stocked stands are thinned, the pruning of selected crop trees occasionally may be advisable. Because it is difficult to select final crop trees in the sapling stage, however, the number selected for pruning in this stage should be greater than that actually expected at the final harvest.

Pruning should begin in the sapling stage, since, if delayed too long, costs increase, probable benefits decrease, and fungi may attack the trees after limbs containing heartwood are removed. For these reasons, trees with branches more than two inches thick should usually not be pruned.

Pruning should always be done close to the main stem so as not to leave stubs. Curtis (138) and Anderson (9), working with other conifers, found that following ordinary pruning dead knots did not heal over as quickly as live ones, but healed over more quickly when the cut removed the collar at the junction of the branch and stem. This accelerated healing was attributed to the stimulus from cutting into the cambium layer. The flow of pitch also lessened the possibility of fungus attack on the exposed cut.

If up to 200 selected trees per acre are pruned when they are not more than 3 or 4 inches in diameter and have limbs less than 1 inch thick, crop values will be enhanced greatly (428). When trees are 5 or more inches in diameter, however, pruning may sometimes be combined advantageously with commercial thinnings and limited to perhaps 100 to 150 selected trees per acre. At this stage, final crop trees can be selected with enough certainty to avoid the expense of pruning many trees that will be removed in preharvest cuttings.

Until an open-grown longleaf pine reaches 18 feet in height, it cannot stand heavy pruning of live branches without an appreciable retardation of growth. The lower half of open-grown 18-foot saplings may be pruned in the first operation. Later, in a second operation when the trees are about 34 feet high, all branches may be removed to a height of 17 feet, thus clearing one 16-foot log. If only one pruning of the butt-log section is contemplated, it should be deferred until the trees are about 34 feet high. Experiments in open-grown stands have shown that live branches from the lower third of the crown, or half the total height, may be removed with slight effect on growth. As a rule, 40 percent of the height of an open-grown longleaf pine may be pruned without loss of growth, and 50 percent with a slight loss (63).

According to Mattoon (386), the essentials of pruning southern pines are as follows: Prune (1) small or young selected trees—sound, straight, thrifty, evenly spaced, and promising for high-quality products; (2) close to the tree trunk, so as to leave no stub; (3) not more than two-thirds of the total height of the tree, or more than the lower one-third of the live crown or top; and (4) a second time, if necessary, to produce at least one clear 16-foot log and, on the best grade of tall timber, to get two 16-foot logs.

Pruning may be done at any time of year, although winter is probably best, especially for small operations. Pruning during severe drought may induce insect attacks.

Pruning Tools and Costs

The size, arrangement, and height of branches to be pruned should determine the choice of pruning tools. Axes are not suitable for the close, flush cuts that promote prompt healing without infection. A man standing on the ground can remove with sturdy long-handled shears limbs 2 inches thick, both dead and alive, up to a height of 7 or 8 feet. Saws are more desirable than shears since they cut more closely. A hand cross-cut saw with coarse incurved teeth is generally considered the best tool for pruning up to 7 or 8 feet. A light 12-foot ladder facilitates pruning to a height of 17 feet with a hand saw, but in experienced hands a pole saw is faster. Pole saws should have narrow, rigid blades, about 16 or 18 inches long, with 5 to 7 teeth per inch filed to cut on the pull stroke. Handles are generally 9 to 12 feet long, but may be much longer. Longleaf pine is comparatively easy to prune with pole saws because long internodes separate the branches and small whorls. Undercuts are not necessary because the sawed branches break off without stripping bark from below. Few branches are small enough to stick to or catch the saw.

The time needed to prune 3- to 8-inch open-grown longleaf to various heights is shown in Table 63. On more than 2,000 acres of mixed longleaf and slash pines, pruning costs by Civilian Conservation Corps enrollees in Florida in 1940 averaged about \$2 per acre, based on labor at \$1.50 per man-day. Pruning of small trees 2 to 6 inches in diameter, 241 trees per acre, averaged \$0.0083 per tree; and of larger trees 4 to 8 inches in diameter, 81 per acre, \$0.0256 per tree.

Table 63.—Average time required to prune open-grown longleaf pine¹ (After Bull)

Pruning height (feet)	Diameter breast high (inches)—					
	3	4	5	6	7	8
	Man-hours	Man-hours	Man-hours	Man-hours	Man-hours	Man-hours
0 to 7	0.005	0.005	0.006	0.006	0.006	0.006
0 to 8	.007	.007	.008	.008	.008	.009
7 to 12	.009	.012	.015	.018	.020	.023
8 to 12	.007	.011	.014	.018	.021	.023
12 to 17	.014	.016	.020	.026	.034	.044
8 to 17	.020	.025	.033	.041	.043	.056
17 to 25	.029	.035	.055	.083	.112	.143
0 to 7 + 7 to 12 + 12 to 17	.028	.033	.041	.050	.060	.073
0 to 8 + 8 to 17	.027	.032	.041	.049	.056	.065

¹Based on efficient workmen and good saws. To convert these figures of working time to elapsed or total time required, 50 percent should be added; if a ladder is used, 60 percent. For example, the approximate time needed to prune, in 2 operations, 100 5-inch trees per acre to a height of 17 feet is 4.1 + 2.05, or 6.15 man-hours.

HARVEST CUTTINGS

Silvicultural Systems

The principal silvicultural systems under which forests are reproduced in sustained-yield management are (1) shelterwood, (2) selection, and (3) clear cutting.

Shelterwood is unsuited to the more intolerant species of trees. If longleaf pine is reproduced under the shelterwood system, numerous seed trees must be removed promptly after seedling establishment; the seedlings neither require shelter nor tolerate it long enough to emerge from the grass.

The selection system is designed to produce all-aged stands. Longleaf will not reproduce itself in such a forest, whether the selection is by single trees or by small groups. Various adaptations of the selection system known as selective cutting, selective timber management, selective logging, maturity selection, etc., are likewise unsatisfactory for longleaf. No system that substitutes light and frequent partial cuttings for heavy seed cuttings and final harvests is suitable for the reproduction of an intolerant species like longleaf pine.

Clear cutting appears to be the best system for longleaf because the species must be reproduced in even-aged stands. (Phases in the natural development of even-aged stands are illustrated in Plates 44 and 45.) Clear cutting can be a method of destruction or of silviculture. In the past it has often been destructive because the few trees left were inadequate for reseeding, the intervals between subsequent fires were unsuitable, or hogs were abundant. New stands may originate from seed trees (scattered or in groups), adjacent uncut timber, or planting, but so many clearings have failed to reproduce to longleaf that the requirements for reforesting clear-cut areas deserve further study before definite recommendations can be made.

Silviculture should be designed to take advantage of the form of the natural forest. Most well-stocked longleaf forests are even-aged, but the usual understocked forests are patchy and irregular. So long as a longleaf forest remains poorly stocked, it can continue to grow in many-aged groups but cannot reproduce itself satisfactorily. Seedling stands do best in large, cleared areas.

Longleaf pine in understocked stands is actually being handled in both even-aged and several-aged stands, but only under even-aged management can it make full use of the soil over long periods. Seed dispersal from adjacent timber will not reseed clearings much larger than an acre. Smaller clearings will reseed more thoroughly from the side, but few of the seedlings can grow. It has been found that no longleaf regeneration can thrive within about 30 feet of the base of a mature longleaf tree (113), hence about 44 percent of the area in a circular 1-acre clearing will be devoid of effective regeneration as long as the bordering timber remains uncut. Smaller clearings have an even smaller productive area.

Clear cutting (except for seed trees left in groups or scattered over the area) is the cheapest effective method of obtaining extensive even-aged new stands. No portion of a clearing should be more than about 100 feet from a seed tree. Four well-spaced seed trees per acre (about 104 feet apart) will, theoretically, reseed 74 percent of a given area, since seedlings will come in but cannot thrive under seed trees. If the latter are long retained, therefore, seedlings below and adjacent to them must be sacrificed. On the other hand, if seed trees are removed as soon as the area is well restocked, the entire new stand should develop satisfactorily. Timely release of longleaf reproduction under seed trees has resulted in many fine stands.

Seed Tree Methods

In using clear cutting with seed trees the usual procedure is to remove the trees as soon as there are a sufficient number of well established and well distributed seedlings. As noted in Chapter V, good longleaf reproduction can usually be obtained from a single heavy seed fall in 10 years, or less, if seedbeds are properly

prepared and maintained. If conditions are not right, it may be necessary to wait for a second good seed fall, which usually involves considerable delay. Seed trees meanwhile increase in diameter, seed-bearing capacity, and value. Seed trees should not be cut until seedlings are at least 2 years old, since an accidental fire may destroy a stand of younger seedlings.

A modification of the usual seed-tree system provides for retaining seed trees for a considerable period in order to obtain a great increase in value. Needed regeneration can be secured incidental to investment in the growth of the trees, but it will be on adjacent areas, not under the trees, since longleaf reproduction and seed trees¹ are mutually exclusive. Chapman and Bulchis (113) suggest that about half of a reproducing longleaf forest be devoted to the further development of seed trees and half to new growth. Their recommendations are as follows:

"1. At time of final cutting of a mature stand, cut heavily; leave large openings, but leave from 4 to 6 well-formed and pruned seed trees, with crowns averaging 40 feet in length, per acre, each preferably isolated. Trees 8 to 11 inches in d.b.h. will do.

"2. Do not expect a full stand of reproduction under these trees, but anticipate that each will maintain itself for a 40-year period against any encroachment of reproduction, and will in that time produce the cream, or profit from high-grade sawlogs.

"3. After 40 years, the reproduction will be old enough to seed in these blanks that will be left by cutting the seed trees. This plan would produce stands composed of two age classes, differing in age by 40 years, with an 80-year rotation for sawlogs, and intermediate operations for pulpwood, posts, poles, and piling."

In support of their contention that longleaf seed trees can be profitably reserved for future growth, Chapman and Bulchis have reported their observations on such trees at Urania, La. (Table 55). Based on an average cost of logging and manufacture of \$23 per M board feet, 20 trees—averaging 75 board feet each—were submarginal for saw timber when reserved. After 31 years of growth they averaged 312 board feet each, 73 percent of which was No. 1 Common and better grades of lumber. Thus, at the above cost for logging and manufacture, conversion of the average tree cost \$7.18. Subtracting this from the sales value (\$10.73) of its lumber content, leaves \$3.55 per tree as a margin for stumpage and profit, or \$11.38 per M board feet.

Often seed trees were not left in harvesting old-growth longleaf because the owners would not forego immediate cash values. In this connection, Chapman and Bulchis state that profits from seed trees can cover all carrying charges on a new crop, plus interest on the original investment in reserved trees. For the above example, 1 typical seed tree per acre returned in 31 years, at 4 percent compound interest, a value equal to an annual expense of 15 cents for taxes and administration. Two such seed trees would more than reimburse a landowner for carrying charges; that is, regeneration could be obtained as a byproduct of a profitable investment in seed trees. It may occasionally be desirable to carry a few of the best trees through 2 rotations in order to get premium prices for unusually large timbers.

¹See above, pages 70-78, for evidences of good seed production and seed-tree requirements per acre.

INTEGRATED PRODUCTION

The harvesting of several products adds to the profits derived from forest land. Saw timber is available only from the larger and better trees, while pulpwood can be cut from the smaller and inferior trees and from the otherwise unmerchantable tops of larger trees. Intensive management primarily for high value products, such as sawlogs, ultimately should provide sufficient pulpwood to meet all requirements.

Many longleaf trees are turpentine before being utilized for wood products. Turpentine leaves a 6-foot or longer butt section which cannot always be utilized, but which may return a revenue equivalent to that derived from the same volume of saw timber (165). Butt portions, often pitchy and charred, can sometimes be cleaned sufficiently with an ax to make them acceptable for low-grade pulpwood, posts, or other products. On the other hand, it may be wise to refrain from turpentine trees that are suitable for the production of high-grade timbers to meet the exacting specifications of some export markets.

Financial Maturity and Markets

Forests grown in even-aged form must be harvested stand by stand as each matures. Stands should be retained until the maximum returns per acre per year are realized or until growth culminates, i.e., until current annual increment no longer exceeds mean annual increment. Turpentine should be so planned that most of the trees are not worked out before the stand as a whole is financially mature. Economic maturity² need be determined only approximately, say to the nearest decade, since the natural regeneration process usually requires some 10 years. Some of the smaller trees, which will probably be financially immature at the final harvest, must nevertheless be removed, unless they can qualify as seed trees, in order to permit full occupation of the area by a new stand. Such seed trees may still be financially immature when they have served their purpose as seed trees and are cut. All overstory trees, as already observed, must be cut when complete reproduction is obtained and begins to be affected adversely by competition.

On the other hand, the degree of financial maturity of individual trees, as indicated by their size and condition in relation to merchantability for different products, should be considered in selecting those to be removed in intermediate cuttings.

When the present equivalent of an estimated future value drops below the present realization value, further growth for a particular commodity may be unprofitable. Pulpwood trees, especially poorly formed individuals, are relatively small at financial maturity. Table 64 indicates that, from the standpoint of pulpwood production alone, longleaf pines growing 2 inches in diameter in 10 years mature at 10 or 11 inches in diameter (blocked figures); those growing only half as fast mature at 8 inches, and those growing only $\frac{1}{2}$ inch in 10 years mature at 6 inches.³

²Economic or financial maturity is the age (or size) at which a tree or stand will no longer increase in value fast enough to earn a satisfactory rate of return.

³To cut and pen a unit of rough wood (160 cubic feet gross volume) takes 4 man-hours for round trees 14 inches in diameter, and $8\frac{1}{4}$ man-hours for round trees 5 inches in diameter. Transportation is the chief item of cost in pulpwood products. Most pulpwood is hauled by truck, although hauls up to 300 miles or more are made by rail or barge (Pl. 46). Worthington and Yencso (615) found that transportation accounted for 52 percent of total production costs in a 12-mile haul for 5-inch trees, and 69 per-

Table 64.—*Valuation of longleaf pine trees for pulpwood as affected by size, diameter growth rate, and time held before cutting*¹ (After Bickford)

Present diameter breast high (inches)	Present stumpage value (cents)	Growth 2 inches in 10 years		Growth 1 inch in 10 years		Growth ½ inch in 10 years	
		Value when—		Value when—		Value when—	
		Held 5 years	Held 10 years	Held 5 years	Held 10 years	Held 5 years	Held 10 years
		Cents	Cents	Cents	Cents	Cents	Cents
4	0.1	0.74	1.62	0.41	0.61	0.21	0.34
5	0.9	1.97	3.11	1.31	1.62	1.05	1.09
6	2.4	3.78	4.58	2.87	3.10	2.42	2.36
7	4.6	5.58	7.57	4.68	4.59	4.23	3.85
8	6.8	9.22	10.20	7.38	7.56	6.48	6.07
9	11.2	12.41	12.37	10.81	10.40	9.94	8.88
10	15.1	15.04	15.16	13.72	12.34	13.05	11.57
11	18.3	18.43	17.78	16.72	15.12	15.85	13.75
12	22.4	21.60	19.23	20.00	17.75	19.13	16.42
13	26.3	23.40	21.00	22.50	19.26	21.95	17.82

¹Based on 1938 prices and a discount rate of 4 percent compounded. Blocks indicate d.b.h. beyond which it is unprofitable to hold trees, since at larger diameters the future discounted values fall below the appraised present values. Growth rates may be changed, of course, by stand treatments.

The decision to cut trees or reserve them for future use is often based on current market prices, but the potentially profitable future uses or combinations of uses should also be considered. The effect on expectation values⁴ of postponing use for various lengths of time is shown in Figure 72 for trees 6, 9, 10, and 16 inches d.b.h. on sites prevailing near Olustee, Fla. A falling curve indicates that postponement of utilization is unprofitable. For 16-inch trees, sawlogs are apparently the only product for which cutting can profitably be deferred as much as 5 years. For 10-inch trees, however, the production of sawlogs and naval stores separately or combined, or naval stores and pulpwood combined, may be postponed 10 years or longer without loss. If there is a market for pulpwood only, deferring the utilization of 9- and 10-inch trees is uneconomical, and even 6-inch trees increase very little in value if reserved. By and large, trees should be chosen for removal or reservation on the basis of their condition and spacing, factors which determine their capacity for profitable further development.

Brewster (49) offers the following suggestions for marketing forest products in the longleaf pine region:

“1. Try to market small pine thinnings in the form of treated posts, fence pickets, corral and barn poles, and other round products.

“2. Keep a living inventory of pole trees by length and class and arrange with pole buyers to sell against this list at premium price.

cent for 14-inch trees. For a 26-mile haul, transportation comprized 68 to 81 percent of total production costs. (Fourteen-inch trees, however, are seldom cut for pulpwood, being worth more for poles, piles, or logs.)

In 1935, with pulpwood selling at \$5 per cord at the mill, stumpage was \$0.75, cutting cost \$1.00, and transportation \$2.25, leaving \$1.00 for profit (150). In 1943 pulpwood was bringing \$8.00 a cord; stumpage for the more accessible wood was \$1.50 a cord, but profits rarely reached \$1.00 per cord.

⁴Expectation value is the present worth of all estimated or expected future products (discounted value), or capitalized net-income value.

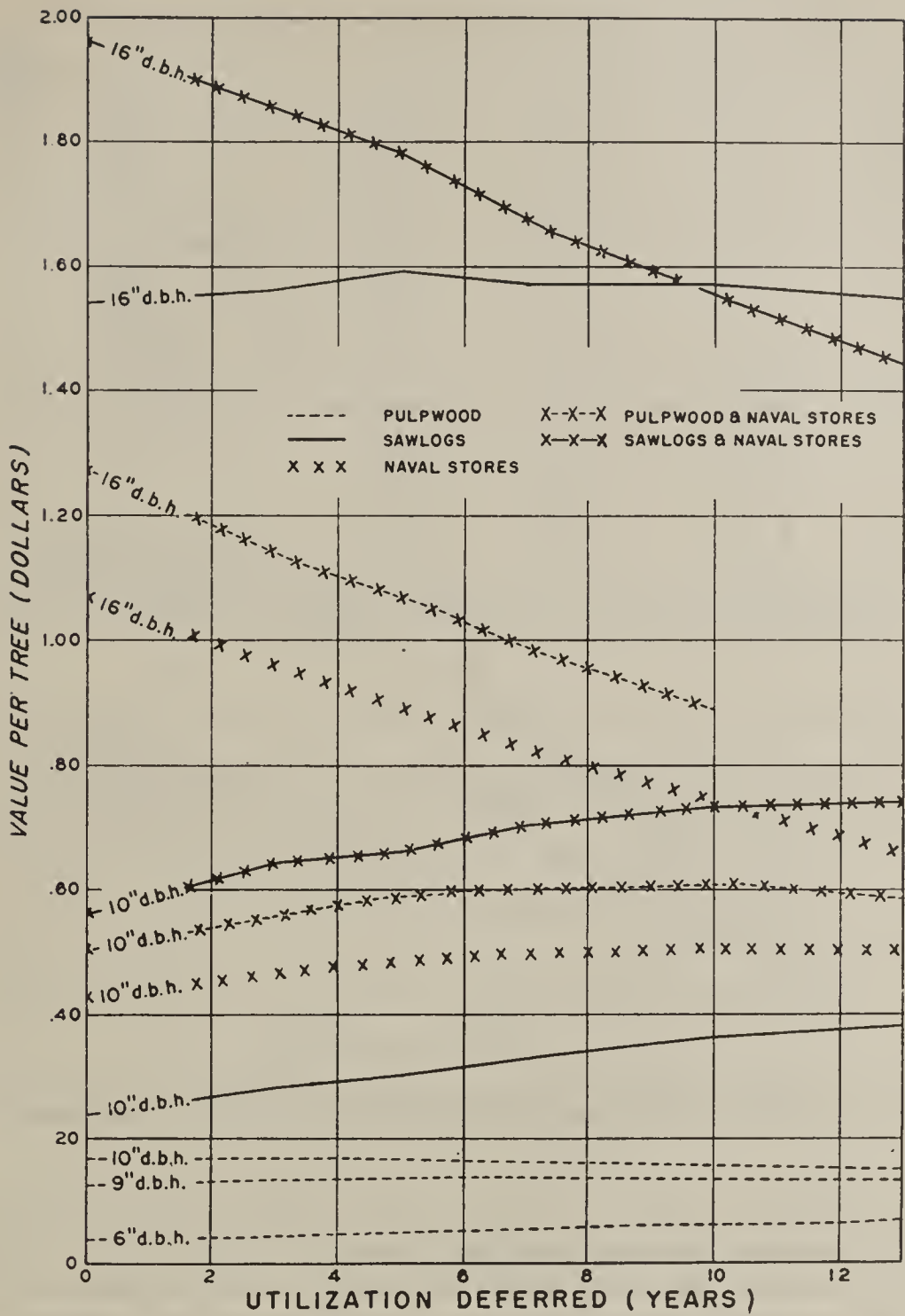


Figure 72.—Effect on present values of merchantable second-growth turpentine pines, of different sizes, resulting from deferring their utilization for various purposes. Based on volumes by Scribner Decimal C log rule, 1938 prices, a compound interest rate of 4 percent, and average growth rates near Olustee, Fla. (After Bickford)

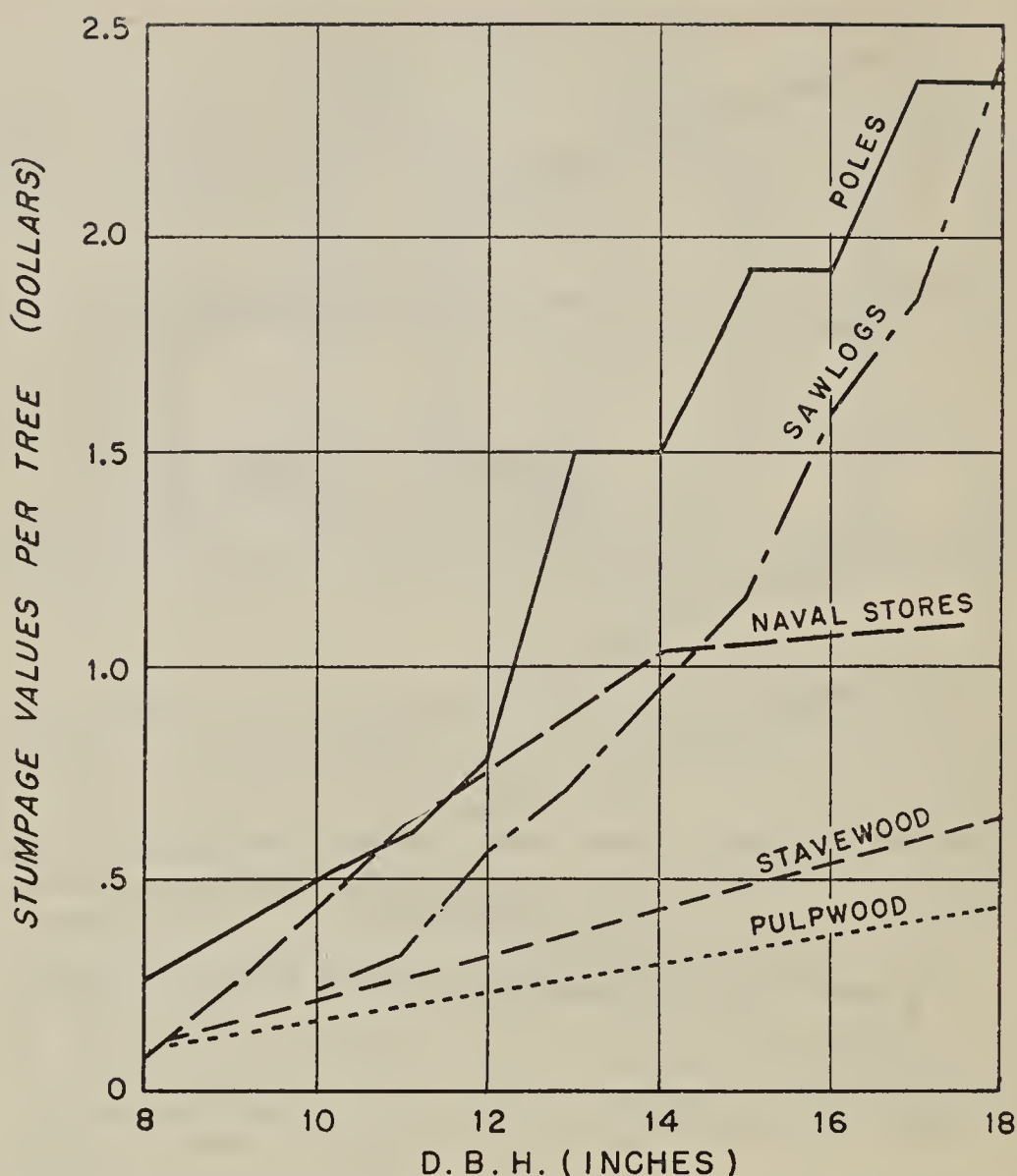


Figure 73.—Stumpage values, 1938, for second-growth turpentine pines in northern Florida by tree sizes. Note the spread in value of the larger trees when used for different purposes. (After Bickford)

"3. Market intermediate cuttings as cross ties, stave bolts, conduit blocks or pulpwood or other products to obtain the best price.

"4. In cutting saw timber, sell the best logs for veneer if possible, sell larger and better remaining logs for delivery to a bandmill, and cut small, low-grade logs on own portable sawmill to make lumber for roofer sales or local use; produce heading, staves, box shooks, etc., from slabs and short logs and edgings if marketable.

"5. Sell stumps and lightwood when young growth is not present."

Maximum profits from forest stands can be obtained only if the owner is familiar with the prices paid locally for all classes of wood products. Removal of merchantable timber in tree lengths, and bucking them into the most valuable prod-

Table 65.—*Stumpage values¹ of superior longleaf and slash pines, sold for various uses*

Pile and pole length (feet)	Butt diameter	Top diameter	Stumpage value of tree for—			
			Piles and poles	Lumber	Ties	Pulpwood
	<i>Inches</i>	<i>Inches</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
30	{ 10¾	7	0.48	0.80	0.60	0.17
	{ 12½	8	1.20	1.05	1.04	.22
35	{ 12½	8	1.40	1.05	1.10	.25
	{ 13	8¼	1.20	1.05	1.10	.28
40	{ 13	8	1.92	1.45	1.42	.31
	{ 13-9/10	8¼	1.50	1.45	1.42	.32
45	{ 13	8	2.16	1.70	1.42	.34
	{ 14½	8¼	2.10	2.00	1.86	.41
50	{ 13½	7	2.80	1.80	1.48	.37
	{ 15	8¼	2.88	2.00	1.86	.47
55	{ 13½	7	3.30	1.68	1.54	.41
	{ 15½	8¼	3.40	2.60	1.98	.54
60	{ 14	6	4.32	2.10	1.54	.43
	{ 16	8¼	4.80	3.35	2.30	.62
65	{ 14	6	5.20	2.20	1.86	.46
	{ 16½	8¼	6.00	3.35	2.80	.70
70	{ 14	6	6.44	2.20	1.86	.50
	{ 17	8¼	7.20	4.20	2.80	.77
75	17¼	8¼	9.20	4.20	2.80	.86

¹Stumpage values for piles, poles, and ties, estimated to be 40 percent of f.o.b. car prices; lumber \$10 per M bd. ft.; and pulpwood, \$1.50 per unit. Car prices as of December 1942, Jacksonville, Fla. (274).

ucts at a central concentration point, is a promising method for obtaining highest returns (Pl. 47).

Longleaf posts, ties, poles, and piles are made to order for special markets. Longleaf poles are said to be more easily and cheaply peeled than poles cut from other southern pines. Some stands worked out for turpentine have yielded \$50 to \$60 worth of poles and piles per acre (227).

A piling market for tall, slender, well-formed trees will exist probably as long as supplies are available. Many tall, old-growth trees 9 to 10 inches in diameter, which make long poles and piles, should not be retained as growing stock because of constricted tops, slow growth, thin sapwood, and gum yields too small to pay for turpentine. Second-growth trees of this size, however, often yield only short poles—under 40 feet—and are more valuable as growing stock. Unscorched turpentine faces may often be included in the merchantable length of piles and poles.

In northern Florida in December 1942, stumpage values of superior trees suitable for poles or piles averaged about 40 percent of the f.o.b. car prices at Jacksonville. With lumber at \$10 per M board feet and pulpwood at \$1.50 per unit (160 cubic feet), such trees brought \$0.17 to \$0.86 as pulpwood, \$0.60 to \$2.80 as ties, \$0.80 to \$4.20 as lumber, and \$0.48 to \$9.20 as piles or poles (Table 65).⁵

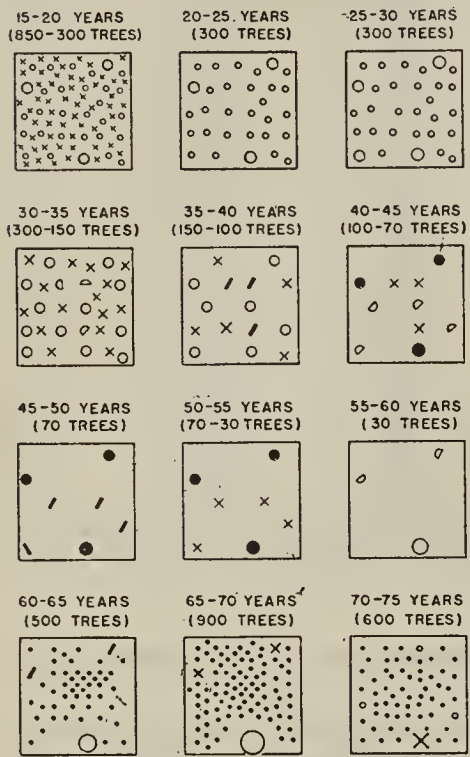
Schedules for Integrated Production

In the long run, most forests can be managed to the greatest advantage by planning for the combined production of a principal high-value crop and auxiliary low-value or special products (pulpwood, posts, ties, or blocks for cross arms). The

⁵At 1943 stumpage values, southern pine was worth about 2 cents per cubic foot of solid wood as pulpwood and at least 4 cents per cubic foot as saw timber.

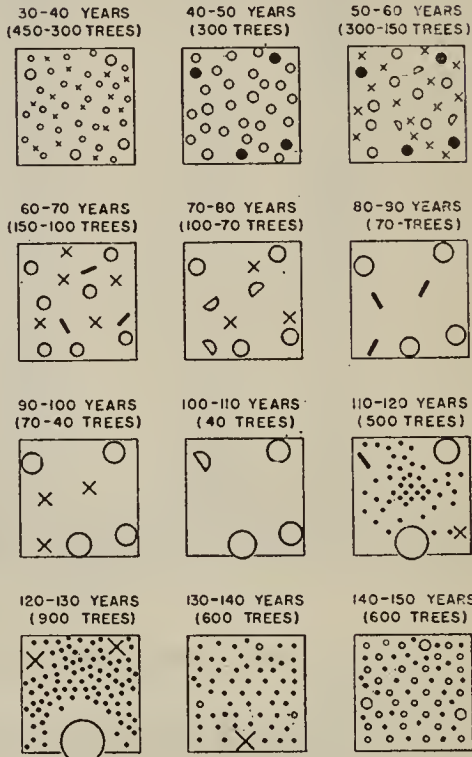
MANAGEMENT MAINLY FOR NAVAL
STORES AND PULPWOOD

(50 TO 80 YEARS ROTATION)



MANAGEMENT MAINLY FOR
SAW TIMBER

(80 TO 120 YEARS ROTATION)



- SEEDLINGS
- SAPLINGS
- SMALL POLE
- LARGE POLE
- ◡ FRONT FACE
- ◡ BACK FACE
- ROUND TREES
- × CUT IN THINNING OR HARVEST

Figure 74.—Schedules for managing even-aged longleaf pine stands for continuous integrated production. Each square represents 1/10 acre; figures in parentheses are numbers of trees per acre.

disposal of inferior trees, and sale of minor wood products, facilitates the economic production of superior trees and major products.⁶

The opportunity for profitable integrated production of diverse forest products is suggested by the increasing spread in value of the larger second-growth trees (Fig. 73). This may be accomplished by selecting the best trees—or their major portions—for the most profitable uses, and relegating to less profitable uses the poorer trees and minor portions of the best. The best trees are straight, vertical-stemmed, clean-boled with thrifty tops covering about one-third to two-fifths of the height, and capable of sustained rapid growth in volume and value. Harvesting inferior trees from time to time turns over operating capital, thus supporting the long-term rotation needed by the better trees to attain dimensions for high-grade products.

⁶Small trees often serve as silvical trainers, crowding the tops and facilitating the natural pruning of the stems of larger trees. Later the more vigorous trainers become aggressive competitors for space. Sale of these competing trees is desirable—even if it only covers the cost of removal—in order to give adequate space to the more productive trees.

Figure 74 shows how well-stocked longleaf stands may develop under 2 different objectives of management. The stated rotation periods, varying from 50 to 120 years, actually have little significance. The longer periods, if used at all, are needed only for the production of large, high-grade saw timber. The short rotations, which are more popular, must be adapted to the site and the economy of the region, and need not be set in advance. Stand density is shown at 5- or 10-year intervals, and although specific numbers of trees are listed, there is actually a great deal of flexibility in such schedules. No single rigid schedule has been proved conclusively superior to all others, and none probably ever will be determined.

Although the densities shown at the beginning of each series of diagrams in Figure 74 represent good stocking, they are considerably lower than normal yield-table densities for the same ages and, therefore, much more likely to be attained. The first thinnings might be made earlier or later than shown, depending on density, expression of dominance, and degree of competition.

Some seedlings may spring up in open stands before the rotation is completed, and some seed trees will be retained beyond the average felling age. Most overtopped longleaf seedlings will die or be stunted if they survive, and are not shown in the diagrams. Some scattered seedlings may be sacrificed to prepare a site for adequate even-aged regeneration. The removal of overwood trees should be properly timed. Seedbed preparation and seed years must be synchronized. Of course, plans for the new crop may miscarry; hence, unless planting funds are available, seed trees should not be harvested until the forest floor is carpeted with enough thrifty 2-year-old or older seedlings to make a satisfactory stand. If the regeneration process is handled properly, so that a heavy seed crop results in a successful catch, there will be no unproductive interval between rotations.

SUMMARY

At present the object of commercial forest management is often simply to attain or maintain profitable production of forest products, but ultimately the object should be to sustain the greatest possible financial net return per acre per year.

Natural and economic advantages, such as a long growing season and accessibility to markets, make the South a particularly attractive region for growing timber. The gum naval stores industry was able to weather the transition from virgin to second growth because the soils are predominantly suited to forestry rather than agriculture. It has made rapid strides in adopting modern methods in recent years. Much can still be done to improve timber stocking, increasing the number of worked trees from about 25 to 150 or more per acre on the better sites. Under good turpentine practice, timber should yield about 60 naval stores units per crop instead of 30 or 40 as at present.

A market for diverse wood products provides an opportunity for increasing profits through the integrated production of several items on the same forest property.

A longleaf pine forest should be divided into compartments to control and record progress in forestry operations. Various methods of classifying stands by type, condition, etc., in the compartments are suggested.

Thinnings should usually, but not always, be postponed until the trees removed will pay the entire cost of the operation. The release of trees intended for sawlogs should be deferred, usually, until their stems are clear of live branches or can be pruned to a height of 25 feet or more. Thinnings should not be delayed so long, however, that the crowns shorten to less than about 33 to 40 percent of the height of the trees. Understocked stands often need improvement through the cutting of rough-stemmed dominants but require thinning only where dense groups of trees occur. The thinning of dense stands usually proceeds from below, removing inferior subdominants that are merchantable and that interfere with crop trees. Small unmerchantable trees should be left, and rough dominants cut. The main canopy must be opened, else the trees will not make a worthwhile response in growth. In the early stages of stand development, longleaf pine can be grown nearly as dense as normal-yield tables indicate, but later commercial thinnings should give more space to selected crop trees.

Eradication of weed trees, particularly scrub oaks, is often desirable and can be accomplished by cutting, burning, girdling, or poisoning—separately or in various combinations. Cutting of weed trees for industrial or other use is preferred to eradication, but is possible only in a few places.

Longleaf prunes itself better than all southern pines except slash. If artificial pruning is necessary, it should be done preferably before stems exceed 3 to 4 inches in diameter, and confined to selected crop trees. Longleaf pines are easily pruned with hand and pole saws. Any one operation usually should be limited to the lower third of the crown or lower two-thirds of the tree. The first 17- or 25-foot length of a sawlog tree should ultimately be cleared of branches if pruning is done at all.

Clear cutting, with seed trees scattered or in groups, is recommended for the regeneration of longleaf pine in even-aged stands. Because longleaf seedlings usually do not survive long or make active height growth within about 30 feet of seed trees, small clearings are unsatisfactory. Four 14-inch trees or six 10- to 13-inch trees per acre, well distributed, are sufficient for natural reseeding on favorable sites. If such trees are not left, the larger openings will probably have to be planted to obtain a complete new stand. Where adequate seed trees are left, they must be removed soon after the resulting seedling stand is 2 years old if the new stand under these trees is to survive.

A modification of this method utilizes a cutting cycle of approximately 40 years and a rotation of about 80 years for saw timber, and aims to produce irregular patches of even-aged stands differing in age by 40 years. Each new stand will, in turn, at 40 years of age reseed adjacent openings made by harvesting 80-year-old timber. The object of this method is to cash in on the greatly increased value of small, high-quality seed trees, resulting from rapid growth over a long period, even though reproduction below and near the trees is sacrificed. Under either seed-tree method, it may occasionally be profitable to carry a few of the best trees through 2 rotations in order to obtain premium prices for unusually large timbers.

Grown in even-aged forests, longleaf pine must be harvested as each stand matures, as it is worked out for turpentine, and when it is uniformly reproduced. The rate of growth and financial maturity of individual trees may, however, affect

their selection in intermediate improvement cuttings. The production of naval stores and saw timber from small trees can usually be postponed to advantage. Maximum profits may be expected only if owners are familiar with the prices paid locally for all forest products. Trees suitable for higher uses should rarely be cut for pulpwood; sawlogs, for example, usually bring at least twice as much as pulpwood per cubic foot. Pulpwood is available in large quantities as a byproduct in producing saw timber. Trees that can qualify are usually worth most for piles or poles, next most for sawlogs, less for ties, and least for pulpwood. Since the relative values of saw timber, naval stores, and other products fluctuate with market conditions, forests should be managed so that the proportionate output of each product may be readily modified.

If the many pitfalls that threaten longleaf reproduction can be avoided, the culture of this unusually resistant and fire-hardy tree is relatively easy. Forestry enterprises that possess longleaf pine growing stock can ill afford to disregard the species—one of the finest timber trees the world has known.

APPENDICES

Appendix I

Common Names of Longleaf Pine

The established scientific name for longleaf pine is *Pinus palustris*, from the Latin *palus* or *paluster*, meaning swamp.¹ In the Piedmont counties of Virginia, loblolly pine (*P. taeda*) was at one time called longleaf pine (476).

The following names have been used for longleaf in different localities: "fat" pine in the southern States generally; "longleaved" and "longstraw" pine in the Atlantic States; "turpentine" and "rosemary" pine in North Carolina; "brown" pine in Tennessee; and "orchard" pine in Texas. In the lumber trade, longleaf pine has been called "southern," "yellow," "hard," "heart," and "pitch" pine. "Broom" pine has appeared in botanical literature occasionally.

Longleaf pine timber imported into France in the nineteenth century was usually called "pichepin," apparently a corruption of pitch pine.

Any narrow-ringed, hard-textured southern yellow pine—whether longleaf, slash, shortleaf or loblolly—has been sold as longleaf, and the wider-ringed, softer-textured, sappy pine as shortleaf. In fact, in the early standard specifications for structural timbers issued by the American Society for Testing Materials, "longleaf" was used to identify the quality of the wood and not for botanical purposes. This confusion of longleaf with other pines is natural because the species cannot always be distinguished botanically on the basis of the wood alone.

¹Some of the discarded scientific names, according to Dallimore and Jackson (140), are *Pinus australis* Michaux; *P. georgica* Hort.; *P. longifolia* Salisbury (not Roxburgh); *P. lutea* Walters (not Loddiges); *P. palmieri* Manetti; and *P. serotina* Hort. (not Michaux).

Appendix II

Some Characteristic Flora of the Longleaf Pine Belt

No single compilation of all the plants typical of the longleaf pine belt is available. The existing county and State lists of plants associated with longleaf pine are incomplete and sometimes inaccurate. Obviously, the flora varies with place and time as natural succession progresses.

The names used here have been changed, where necessary, from those originally published to conform with the nomenclature adopted by the U. S. Forest Service. No lists of flora for the longleaf pine type of forest in South Carolina are given. In general, the South Carolina forest communities resemble those of North Carolina in the physiographic regions along the coast. Longleaf occupies the lower pine belt or savanna region, the upper pine belt, the red hill region, and the sandhill region.

A. Pine Barrens

(After Harper (240))¹

THE ALTAMAHA GRIT REGION OF GEORGIA

DRY SITES

Trees

- Diospyros virginiana* L., Common persimmon
- Pinus palustris* Mill., Longleaf pine
- Quercus cinerea* Michx. [syns. *Q. brevifolia* (Lam.) Sarg.; *Q. incana* Bartr.], Bluejack oak
- Q. laevis* Walt. (syn. *Q. catesbaei* Michx.), Turkey oak
- Q. marilandica* Muenchh., Blackjack oak
- Q. falcata* Michx. [syn. *Q. digitata* (Marsh.) Sudw.], Southern red oak
- Q. stellata* var. *margaretta* (Ashe) Sarg. (syn. *Q. margaretta* Ashe), Dwarf post oak

Shrubs

- Amorpha herbacea* Walt., Clusterspike amorpha
- Asimina angustifolia* A. Gray, Slimleaf pawpaw
- A. incana* (Bartr.) Excell (syn. *A. speciosa* Nash), Woolly pawpaw
- Castanea alnifolia* Nutt., Trailing chinquapin
- Ceanothus americanus* L., Jerseytea ceanothus
- C. microphyllus* Michx., Tinyleaf ceanothus
- Chrysobalanus oblongifolius* Michx., Gopher-apple
- Crataegus uniflora* Moench, Oneflower hawthorn
- Elliottia racemosa* Muhl., Elliottia ("Southernplume")
- Gaylussacia dumosa* (Andr.) Torr. and Gray, Dwarf huckleberry
- Ilex glabra* (L.) A. Gray, Inkberry; Gallberry
- Lyonia mariana* (L.) D. Don [syn. *Pieris mariana* (L.) Benth. and Hook.], Staggerbush lyonia
- Myrica pumila* Michx., Dwarf waxmyrtle

¹Harper also listed about 110 species of minor plants such as herbs and vines. The great majority of species and individuals were perennial herbs. The total of some 137 species represents 100 genera and 38 families. Most abundant were the *Compositae* with 25 species, and *Leguminosae* with 23 species. About 16 percent of the angiosperms were monocotyledons. One of the grasses, *Aristida stricta*, is more abundant in this region than all other herbaceous vegetation combined.

Polycodium floridanum (Nutt.) Greene (syn. *P. caesium* Greene),² Florida deerberry
Quercus pumila Walt., Running oak
Rhus copallina L., Shining sumac
Rubus trivialis Michx., Southern dewberry
Serenoa repens (Bartr.) Small (syn. *S. serrulata* Michx.), Sawpalmetto
Vaccinium myrsinites Lam. (syn. *V. nitidum* Andr.), Ground blueberry

²Many botanists regard *Polycodium* as inseparable from *Vaccinium*.

INTERMEDIATE SITES¹

Trees

Pinus caribaea Morelet (syn. *P. elliottii* Engelm.), Slash pine
P. palustris Mill., Longleaf pine
P. rigida var. *serotina* (Michx.) Loud. (syn. *P. serotina* Michx.), Pond pine

Shrubs

Asimina incana (Bartr.) Excell (syn. *A. speciosa* Nash), Woolly pawpaw
Castanea alnifolia Nutt., Trailing chinquapin
Gaylussacia dumosa (Andr.) Torr. and Gray, Dwarf huckleberry
G. frondosa (L.) Torr. and Gray, Dangleberry
Hypericum myrtifolium Lam., Heartleaf St. Johnswort
H. opacum Torr. and Gray, Pitseed St. Johnswort
Ilex glabra (L.) A. Gray, Inkberry; Gallberry
Kalmia hirsuta Walt., Sandhill kalmia
Lyonia ferruginea (Walt.) Nutt. [syn. *Xolisma* ("Cholisma") *ferruginea* (Walt.) Heller],
 Rusty lyonia
L. mariana (L.) D. Don [syn. *Pieris mariana* (L.) Benth. and Hook.], Staggerbush lyonia
Myrica pumila Michx., Dwarf waxmyrtle
Quercus pumila Walt., Running oak
Rhododendron nudiflorum (L.) Torr. (syn. *Azalea nudiflora* L.) Pinxterbloom azalea
Serenoa repens (Bartr.) Small (syn. *S. serrulata* Michx.), Sawpalmetto
Vaccinium myrsinites Lam. (syn. *V. nitidum* Andr.), Ground blueberry

¹In addition to the 3 pines and 15 shrubs named here, about 80 minor plants were listed. On these sites also the perennial herbs predominated. The 98 species represent 70 genera and 33 families. *Compositae* constituted a fifth, but the largest genus was *Polygala*, with seven species. Here 22 percent of the angiosperms were monocotyledons. Biennial herbs were a little more numerous than the annual ones.

MOIST SITES¹

Trees

Pinus caribaea Morelet (syn. *P. elliottii* Engelm.), Slash pine
P. rigida var. *serotina* (Michx.) Loud. (syn. *P. serotina* Michx.), Pond pine
Taxodium ascendens Brongn. (syn. *T. imbricarium* Harper), Pondcypress ("Pond bald-cypress")

Shrubs

Aronia arbutifolia (L.) Ell., Red chokeberry
Ascyrum stans Michx., Atlantic St. Peterswort
Cliftonia monophylla (Lam.) Sarg., Buckwheat tree
Clethra alnifolia L., Summersweet clethra
Gaylussacia dumosa (Andr.) Torr. and Gray, Dwarf huckleberry

¹In addition to the 3 trees and 21 shrubs there were 163 other plants, or a total of 187 species in 105 genera and about 46 families. The largest families were *Cyperaceae*, with 27 species; *Compositae* with 24; and *Gramineae* with 16. *Rhynchospora* was the largest genus on these moist sites and in the whole region, with 13 species. Over two-fifths of the list were monocotyledons. Two species that become large trees in some other parts of south Georgia, *Liquidambar styraciflua* L. and *Magnolia virginiana* L. (syn. *M. glauca* L.) are only shrubs in these moist pine barrens.

G. frondosa (L.) Torr. and Gray, Dangleberry
Hypericum fasciculatum Lam., Sandbush St. Johnswort
H. myrtifolium Lam., Heartleaf St. Johnswort
H. opacum Torr. and Gray, Pitseed St. Johnswort
Ilex glabra (L.) A. Gray, Inkberry; Gallberry
Itea virginica L., Virginia sweetspire
Kalmia hirsuta Walt., Sandhill kalmia
Liquidambar styraciflua L., Sweetgum ("redgum")
Lyonia (syn. *Xolisma*) sp., Lyonia
L. lucida (Lam.) K. Koch [syn. *Pieris nitida* (Bartr.) Benth. and Hook.], Fetterbush lyonia
L. mariana (L.) D. Don [syn. *Pieris mariana* (L.) Benth. and Hook.], Staggerbush lyonia
Magnolia virginiana L. (syn. *M. glauca* L.), Sweetbay ("Sweetbay magnolia")
Myrica cerifera L. (syn. *M. caroliniensis* Mill.), Southern waxmyrtle
Pieris phillyreifolia (Hook.) DC., Vine pieris
Rhododendron viscosum (L.) Torr. (syn. *Azalea viscosa* L.), Swamp azalea
Styrax americana var. *pulverulenta* (Michx.) Perk. (syn. *S. pulverulenta* Michx.), American snowbell

B. Associated Grasses of the Dry Pine Barrens in Alabama
 (After Mohr (398))

Andropogon tener (Nees) Kunth, Slender bluestem
A. ternarius Michx. (syn. *A. argyraeus* Schult.), Three-stamen bluestem
Anthaenantia villosa (Michx.) Beauv., Green silkyscale
Aristida purpurascens Poir., Arrowfeather three-awn
A. simpliciflora Chapm.,¹ Chapman three-awn
A. stricta Michx., Pineland three-awn
Danthonia sericea Nutt., Downy danthonia
Digitaria filiformis (L.) Koel. (syn. *Panicum filiforme* L.), Slender fingergrass
Gymnopogon ambiguus (Michx.) B. S. P., Bearded skeletongrass
G. brevifolius Trin., Slim skeletongrass
Panicum angustifolium Ell., Narrowleaf panicum
P. aciculare Desv. (syn. *P. arenicola* Ashe), Needleleaf panicum
P. lancearium Trin. (syn. *P. nashianum* Scribn.) (One of the panicums)
P. lanuginosum Ell., Woolly panicum
P. neuranthum Griseb.² (One of the panicums)
P. oligosanthes Schult. (syn. *P. pauciflorum* Ell. not R. Br.) (One of the panicums)
P. scoparium Lam. (syn. *P. pubescens* Lam.), Velvet panicum
P. sphaerocarpon Ell., Roundseed panicum
Paspalum bifidum (Bertol.) Nash, Pitchfork paspalum
P. ciliatifolium Michx., Fringeleaf paspalum
P. diffforme LeConte, Thickspike knotgrass
P. floridanum Michx., Florida paspalum
P. plicatulum Michx., Brownseed paspalum
P. setaceum Michx., Thin paspalum
P. supinum Bosc (syn. *P. dasyphyllum* Ell.), Longleaf paspalum
Sorghastrum elliottii (Mohr) Nash (syn. *Chrysopogon elliottii* Mohr), Slender Indiangrass
S. nutans (L.) Nash [syns. *Chrysopogon nutans* (L.) Benth; *C. nutans* var. *linnaeanus* (Hack.) Mohr], Yellow Indiangrass

¹Hitchcock regards this as a rare species, confined to western Florida and southern Mississippi.

²Probably misidentified. Hitchcock does not attribute this typically Cuban species to Alabama.

**C. The Longleaf Pine Type in Hardin County, Texas
(After Harper)**

Large Trees

- Carya tomentosa* Nutt. [syn. *Hicoria alba* (L.) K. Koch, not Nutt.], Mockernut hickory
Fagus grandifolia Ehrh., American beech
Liquidambar styraciflua L., Sweetgum ("redgum")
Magnolia grandiflora L., Southern magnolia
Nyssa sylvatica var. *biflora* (Walt.) Sarg. (syn. *N. biflora* Walt.), Swamp tupelo; blackgum
Pinus palustris Mill., Longleaf pine
P. taeda L., Loblolly pine
Quercus alba L., White oak
Q. falcata Michx., Southern red oak
Q. laurifolia Michx., Laurel oak
Q. prinus L. (syn. *Q. michauxii* Nutt.), Swamp chestnut oak

Small Trees

- Cornus florida* L., Flowering dogwood
Ilex opaca Ait., American holly
Liquidambar styraciflua L., Sweetgum ("redgum")
Magnolia virginiana L. (syn. *M. glauca* L.), Sweetbay ("Sweetbay magnolia")

Large Shrubs

- Callicarpa americana* L., American beautyberry
Cephalanthus occidentalis L., Common buttonbush
Cyrilla racemiflora L., Swamp cyrilla
Ilex vomitoria Ait., Yaupon
Myrica cerifera L., Southern waxmyrtle
Symplocos tinctoria (Garden) L'Hérit., Common sweetleaf
Vaccinium arboreum Marsh. [syn. *Batodendron arboreum* (Marsh.) Nutt.], Tree sparkle-berry

Small Shrubs

- Ascyrum stans* Michx., Atlantic St. Peterswort
Hypericum aspalathoides Willd., (One of the St. Johnsworts)
Magnolia virginiana L. (syn. *M. glauca* L.), Sweetbay ("Sweetbay magnolia")
Myrica pumila Michx., Dwarf waxmyrtle
Rhus toxicodendron L. [syn. *Toxicodendron quercifolium* (Michx.) Greene], Poisonoak

Herbs

- Andropogon furcatus* Muhl.?, Big bluestem
Baptisia leucophaea Nutt.?, Plains wildindigo
Boltonia diffusa Ell., Boltonia ("Doll-daisy")
Chamaecrista fasciculata (Michx.) Greene, Showy partridge-pea
Chondrophora nudata (Michx.) Britt.
Chrysopsis graminifolia (Michx.) Ell., Grassleaf goldaster
Diodia teres Walt., Rough buttonweed
D. virginiana L., Virginia buttonweed
Eryngium ludovicianum Morong, Louisiana eryngo
Eupatorium leucolepis Torr. and Gray (syn. *E. mohrii* Greene)?, Whitebract eupatorium ("Justice-weed")
E. rotundifolium L., Roundleaf eupatorium ("False-hoarhound")
E. semiserratum DC.?
E. tortifolium Chapm., Twistleaf eupatorium
Euphorbia corollata L., Flowering-spurge euphorbia
E. maculata L., Spotted euphorbia
Helenium tenuifolium Nutt., Bitter sneezeweed
Helianthus angustifolius L., swamp sunflower
Liatris acidota Engelm. and Gray [syn. *Lacinaria acidota* (Engelm. and Gray) Kuntze]

Liatris pycnostachya Michx. [syn. *Lacinaria pycnostachya* (Michx.) Kuntze], Kansas gay-feather
Linum floridanum (Planch.) Trel., Florida flax
Marshallia graminifolia (Walt.) Small, "Barbaras-buttons"
Nama corymbosum (Macbride) Kuntze, Azure nama
Pluchea foetida (L.) DC., Fetid pluchea
Polygala mariana Mill.?, Maryland polygala
Rhexia mariana L.?, Maryland meadowbeauty
Rudbeckia hirta L.?, Black-eyed-susan
Ruellia humilis Nutt. [syn. *R. ciliosa* var. *humilis* (Nutt.) Britt.], Low ruellia
Solidago nitida Torr. and Gray?, Glossy goldenrod
S. odora Ait., Fragrant goldenrod
Stylosanthes biflora (L.) B.S.P., Pencilflower
Tephrosia spicata (Walt.) Torr. and Gray [syn. *Cracca spicata* (Walt.) Kuntze]?, Brownhair tephrosia

D. Some Associates of Longleaf Pine on Mississippi Uplands (After Lowe (358))

Trees

Diospyros virginiana L., Common persimmon
Liquidambar styraciflua L., Sweetgum ("redgum")
Pinus caribaea Morelet, Slash pine
P. echinata Mill., Shortleaf pine
P. taeda L., Loblolly pine
Quercus nigra L., Water oak
Q. stellata Wangenh., Post oak
Sassafras albidum (Nutt.) Nees [syn. *S. variifolium* (Salisb.) Kuntze], Sassafras

Small Trees

Castanea pumila (L.) Mill., Allegheny chinquapin
Cornus florida L., Flowering dogwood
Malus angustifolia (Ait.) Michx., Southern crab (apple)
Prunus americana Marsh., American plum
Quercus cinerea Michx., Bluejack oak
Q. laevis Walt. (syn. *Q. catesbaei* Michx.), Turkey oak
Rhus copallina L., Shining sumac
R. typhina L. [syn. *R. hirta* (L.) Sudw.], Staghorn sumac

Shrubs and Vines

Rhus radicans L. [syns. *Toxicodendron radicans* (L.) Kuntze; *R. toxicodendron* Authors, not L.], Common poisonivy
Viburnum dentatum L., Arrow-wood viburnum

Herbs

Asclepias tuberosa L., Butterfly milkweed
Ascyrum hypericoides L. (syn. *A. crux-andreae* L.), St. Andrews cross
A. stans Michx., Atlantic St. Peterswort
Aster adnatus Nutt., Scaleleaf aster
A. paludosus Ait., Singlestem bog aster
A. patens Ait., Skydrop aster
Aureolaria pectinata (Nutt.) Pennell [syn. *Dasystoma pectinata* (Nutt.) Benth.], Combleaf oakleech
Centrosema virginianum Benth., Coastal butterfly-pea
Chamaecrista fasciculata (Michx.) Greene (syn. *Cassia chamaecrista* Chapm., not L.), Showy partridge-pea
C. procumbens (L.) Greene (syn. *Cassia nictitans* L.), Sensitive partridge-pea

Chrysopsis graminifolia (Michx.) Ell., Grassleaf goldaster
Clitoria mariana L., Atlantic pigeonwings
Cnidoscolus stimulosus (Michx.) Engelm. and Gray (syn. *Jatropha stimulosa* Michx.), Tread-softly
Coreopsis lanceolata L., Lance coreopsis
Eryngium integrifolium Walt. (syn. *E. virgatum* Lam.), Rod eryngo
E. yuccifolium Michx., Button-snakeroot
Gerardia aphylla (Nutt.) Raf., Scaleleaf gerardia
Houstonia purpurea L., Purple bluets
Liatris spicata (L.) Kuntze, Spike gayfeather
L. squarrosa (L.) Willd., Colicroot gayfeather
Polygala grandiflora Walt., Showy polygala
P. lutea L., Orange polygala
P. nana (Michx.) DC., Green polygala
Pycnanthemum flexuosum (Walt.) B.S.P. (syn. *P. linifolium* Pursh), Slender mountainmint
Rhynchosia simplicifolia (Walt.) Wood [syn. *R. reniformis* (Pursh) DC.], Dollarleaf rhynchosia
Rudbeckia hirta L., Black-eyed-susan
Ruellia ciliosa Pursh., Fringeleaf ruellia
Seymeria cassioides (Walt.) Blake [syn. *Afzelia cassioides* (Walt.) J. F. Gmel.], Senna seymeria
Stillingia sylvatica L., Queensdelight
Strophostyles pauciflora (Benth.) S. Wats. (syn. *Phaseolus pauciflorus* Benth.), Small wild-bean
Stylosanthes biflora (L.) B.S.P. (syn. *S. elatior* Swartz), Pencilflower
Tephrosia spicata (Walt.) Torr. and Gray, Brownhair tephrosia
Tephrosia virginiana (L.) Pers., Virginia tephrosia

E. Longleaf Pine Types in Leon County, Fla. **(After Gano (191))**

In the scrub oak forest the scattered longleaf pines were surrounded mainly by three small deciduous oaks: *Quercus laevis* Walt. (syn. *Q. catesbaei* Michx.), the most xerophytic; *Q. stellata* var. *margaretta* (Ashe) Sarg. (syn. *Q. margaretta* Ashe), intermediate; and *Q. cinerea* Michx., found on the lower, moister locations. Other associates were *Q. virginiana* var. *maritima* (Michx.) Sarg. [syn. *Q. geminata* (Sarg.) Small], *Q. virginiana* Mill., and *Diospyros virginiana* L. Among the numerous herbs and grasses, the most abundant were species of *Andropogon* and *Aristida*. These scrub-oak sandhills were surrounded by lower-lying, sandy pinelands.

The dry, sandy longleaf-slash pinelands bore the same oaks and others, *Quercus virginiana* Mill., *Q. marilandica* Muenchh., *Q. pumila* Walt., together with *Crataegus panda* Beadle, *Bumelia lanuginosa* (Michx.) Pers., *Castanea pumila* (L.) Mill., and *Diospyros virginiana* L. Common shrubs were *Rhus copallina* L., *Ceanothus americanus* L., *Ilex vomitoria* Ait., *Vaccinium arboreum* Marsh., *V. virgatum* Ait., *V. stamineum* L., *V. myrsinites* Lam., *V. neglectum* (Small) Fern. (syn. *Polycodium neglectum* Small), *Leiophyllum buxifolium* (Berg.) Ell., *Kalmia hirsuta* Walt., and *Gaylussacia dumosa* (Andr.) Torr. and Gray, the *Ericaceae* being most numerous. Many of the herbs were the same as in the scrub forest. Families prominent in the varied list of chiefly xerophytic herbs were *Compositae*, *Leguminosae*, *Euphorbiaceae*, *Scrophulariaceae*, *Polygalaceae*, and *Labiatae*.

In the more moist flatwoods, longleaf pines were dominant. *Leguminosae*, abundant on the drier sandy pinelands, were not found in the flatwoods. On the margins of bays and ponds, and the edges of the main areas swept by fire, shrubs were in greatest variety. Here were *Quercus myrtifolia* Willd., *Q. virginiana* var. *minima* Sarg. [syn. *Q. minima* (Sarg.) Small], *Q. ilicifolia* Wangenh. [syn. *Q. nana* (Marsh) Sarg.], *Myrica pumila* Michx., *M.*

cerifera L. (syn. *M. caroliniensis* Mill.), *Ilex glabra* (L.) A. Gray, *Hypericum myrtifolium* Lam., *Hypericum galioides* Lam., *Hypericum aspalathoides* Willd., *Hypericum opacum* Torr. and Gray, *Kalmia hirsuta* Walt., *Aronia arbutifolia* (L.) Elliott [syn. *Pyrus arbutifolia* (L.) L. f.], *Rhododendron nudiflorum* (L.) Torr., *R. viscosum* (L.) Torr., *Lyonia lucida* (Lam.) K. Koch [syn. *L. nitida* (Bartr.) Fern.], *L. ferruginea* (Walt.) Nutt. (syn. *Andromeda ferruginea* Walt.), *Vaccinium stamineum* L. [syn. *Polycodium stamineum* (L.) Greene], and *V. myrsinites* Lam. The sawpalmetto, *Serenoa repens* (Bartr.) Small (syn. *S. serrulata* Michx.), was an index of a more or less saturated subsoil. Besides the grasses and *Compositae*, the families most in evidence on this poorly drained soil were: *Eriocaulaceae*, *Juncaceae*, *Liliaceae*, *Orchidaceae*, *Sarraceniaceae*, *Droseraceae*, *Polygalaceae*, *Melastomaceae*, *Onagraceae*, *Gentianaceae*, *Scrophulariaceae*, and *Lentibulariaceae*.

F. Relative Frequency of Occurrence of Woody Plants Associated with Longleaf Pine Stands on 8 Typical Upland Sites, and on 8 Sites in the Flatwoods Region of the Gulf Coast Hammock Lands of Florida
(After Uphof (570))

Species	Lowland site—								Upland site—							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Trees:	Abundance classification ¹															
<i>Pinus caribaea</i> Morel.	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
<i>P. palustris</i> Mill.	5	5	5	5	4	5	5	5	5	4	5	5	3	5	4	4
<i>Quercus cinerea</i> Michx.	—	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—
<i>Q. laevis</i> Walt. (syn. <i>Q. catesbaei</i> Michx.)	—	—	—	—	—	—	—	—	1	—	2	—	—	1	—	—
<i>Q. virginiana</i> var. <i>maritima</i> (Michx.) Sarg. [syn. <i>Q. geminata</i> (Sarg.) Small]	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—
Shrubs:																
<i>Asimina pygmaea</i> (Bartr.) A. Gray	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
<i>A. reticulata</i> Chapm.	1	1	2	—	1	4	1	1	—	1	1	2	—	1	—	4
<i>Befaria racemosa</i> Vent.	1	2	1	—	1	—	1	—	1	—	—	1	1	—	2	3
<i>Ceanothus microphyllus</i> Michx.	—	—	—	—	—	—	—	—	1	—	2	1	—	—	1	1
<i>Chrysobalanus oblongifolius</i> Michx.	2	2	2	—	1	1	3	1	—	2	—	2	1	3	1	1
<i>Garberia fruticosa</i> (Nutt.) A. Gray	—	—	—	—	—	—	—	—	1	—	—	1	—	1	1	—
<i>Gaylussacia dumosa</i> (Andr.) Torr. and Gray	2	1	—	—	1	—	1	—	—	—	—	—	—	—	—	—
<i>Ilex glabra</i> (L.) A. Gray	3	1	2	—	1	2	1	1	—	—	—	—	—	—	—	—
<i>Lyonia lucida</i> (Lam.) K. Koch (syn. <i>Andromeda nitida</i> Bartr.)	1	1	3	3	1	2	—	2	—	2	4	—	2	—	1	—
<i>Myrica cerifera</i> L.	—	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—
<i>M. pumila</i> Michx.	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
<i>Opuntia vulgaris</i> Mill.	—	—	—	—	—	—	—	—	1	—	1	1	1	—	2	1
<i>Osmanthus americanus</i> (L.) Benth. and Hook. f.	—	—	—	—	—	—	—	—	—	—	1	2	—	1	—	—
<i>Pycnothamnus rigidus</i> (Bartr.) Small	—	—	—	—	—	—	—	—	—	1	1	—	—	3	—	—
<i>Quercus myrtifolia</i> Willd.	2	—	1	—	—	2	—	—	—	—	—	—	—	—	—	—
<i>Serenoa repens</i> (Bartr.) Small (syn. <i>S. serrulata</i> Michx.)	5	5	3	5	5	2	3	5	5	3	1	4	1	2	5	3
<i>Vaccinium nitidum</i> Andr. ²	—	1	3	2	1	1	2	2	1	1	2	1	3	—	4	3

¹1, sporadic; 2, sparse; 3, scattered; 4, abundant; and 5, covering.
²Doubtfully distinct from *V. myrsinites* Lam.

G. Some Flora¹ of Longleaf Pine Lands in Southern Louisiana
(After Penfound and Watkins (433))

Species	Stand condition				
	Second growth	Virgin growth		Clear cut	
	Spring	Spring	Fall	Spring	Fall
<i>Andropogon elliottii</i> Chapm.	*	*	—	*	*
<i>A. scoparius</i> Michx.	*	*	*	—	*
<i>A. tener</i> (Nees) Kunth	—	—	*	—	*
<i>A. virginicus</i> L.	*	*	*	*	*
<i>Aristida virgata</i> Trin.	*	*	*	*	*
<i>Ascyrum linifolium</i> Spach	*	*	—	*	—
<i>A. stans</i> Michx.	*	—	*	—	*
<i>Aster adnatus</i> Nutt.	—	*	*	—	*
<i>A. dumosus</i> L.	—	—	*	*	*
<i>Axonopus compressus</i> (Swartz) Beauv.	*	*	*	*	*
<i>Boltonia diffusa</i> Elliott	—	—	*	—	*
<i>Buchnera americana</i> L.	—	*	—	—	*
<i>Campsis radicans</i> (L.) Seem. (syn. <i>Bignonia radicans</i> L.)	—	—	*	—	—
<i>Centrosema virginianum</i> (L.) Benth. [syn. <i>Bradburya virginiana</i> (L.) Kuntze]	—	—	—	*	—
<i>Chamaecrista littoralis</i> Pollard	—	*	—	*	—
<i>Chaptalia tomentosa</i> Vent.	—	*	—	*	*
<i>Chondrophora nudata</i> (Michx.) Britt.	—	*	—	—	*
<i>Chrysopsis graminifolia</i> (Michx.) Ell. [syn. <i>Pityopsis graminifolia</i> (Michx.) Nutt.]	*	*	*	*	*
<i>Crotalaria purshii</i> DC.	—	*	—	—	—
<i>C. sagittalis</i> L.	—	—	—	—	*
<i>Ctenium aromaticum</i> (Walt.) Wood [syn. <i>Campulosus aromaticum</i> (Walt.) Trin.]	—	—	—	*	—
<i>Cynoctonum mitreola</i> (L.) Britt.	—	—	—	—	*
<i>Desmodium marilandicum</i> (L.) Boott [syn. <i>Meibomia marilandica</i> (L.) Kuntze]	—	*	*	—	*
<i>Diodia tetragona</i> Walt.	—	—	—	*	*
<i>Diospyros virginiana</i> L.	—	*	—	—	—
<i>Drosera brevifolia</i> Pursh	—	—	—	—	*
<i>D. intermedia</i> Hayne	—	*	—	—	—
<i>Eleocharis tuberculosa</i> (Michx.) Roem. and Schult.	—	—	—	*	—
<i>Elephantopus nudatus</i> A. Gray	*	*	*	*	*
<i>Endorima uniflora</i> (Nutt.) Barnh.	*	—	*	*	*
<i>Eragrostis elliottii</i> S. Wats.	—	—	—	—	*
<i>E. hirsuta</i> (Michx.) Nees	*	—	*	—	—
<i>E. refracta</i> (Muhl.) Scribn.	—	—	*	—	*
<i>Erigeron vernus</i> (L.) Torr. and Gray	—	*	*	*	*
<i>Eriocaulon decangulare</i> L.	—	—	—	—	*
<i>Eryngium ludovicianum</i> Morong	—	—	—	*	—
<i>Eupatorium semiserratum</i> DC.	—	*	*	*	*
<i>Fimbristylis autumnalis</i> (L.) Roem. and Schult.	—	—	—	—	*
<i>Gaylussacia mosieri</i> (Small) Camp (syn. <i>Lasiococcus mosieri</i> Small)	*	—	—	—	—
<i>Gymnopogon brevifolius</i> Trin.	—	*	*	*	*
<i>Helenium nudiflorum</i> Nutt.	—	*	—	*	—
<i>Helianthus angustifolius</i> L.	—	—	*	—	—
<i>H. heterophyllus</i> Nutt.	—	—	—	*	*
<i>H. radula</i> (Pursh) Torr. and Gray	—	*	—	—	*
<i>Hydrocotyle umbellata</i> L.	—	—	—	*	—
<i>Hypericum gymnanthum</i> Engelm. and Gray	—	—	—	*	—
<i>H. opacum</i> Torr. and Gray	*	*	—	*	—
<i>Ilysanthes dubia</i> (L.) Barnh.	—	—	—	—	*
<i>Juncus aristulatus</i> Michx.	—	—	—	*	—
<i>J. dichotomus</i> Elliott	—	*	—	*	—
<i>J. elliottii</i> Chapm.	—	—	—	*	—
<i>Kyllinga brevifolia</i> L.	—	—	*	—	—
<i>Lespedeza repens</i> (L.) Bart.	—	*	—	*	—
<i>Lespedeza</i> sp.	—	*	—	—	—
<i>Linum medium</i> (Planch.) Britt. [syn. <i>Cathartolinum medium</i> (Planch.) Small]	—	*	*	—	*

¹Asterisk indicates occurrence.

Species	Stand condition				
	Second growth	Virgin growth		Clear cut	
	Spring	Spring	Fall	Spring	Fall
<i>Liquidambar styraciflua</i> L.	*	*	*	—	—
<i>Lobelia brevifolia</i> Nutt.	—	—	*	—	*
<i>L. floridana</i> Chapm.	—	—	—	*	—
<i>Ludwigia linearis</i> Walt.	—	—	—	*	*
<i>Lyonia ligustrina</i> (L.) DC. [syn. <i>Arsenococcus ligustrinus</i> (L.) Small]	—	*	—	—	—
<i>Nyssa sylvatica</i> var. <i>biflora</i> (Walt.) Sarg. (syn. <i>N. biflora</i> Walt.)	—	—	*	—	—
<i>N. sylvatica</i> Marsh.	—	—	*	—	—
<i>Oldenlandia uniflora</i> L.	*	—	—	—	—
<i>Panicum albomarginatum</i> Nash	—	—	—	*	—
<i>P. angustifolium</i> Ell.	*	—	—	—	*
<i>P. barbulatum</i> Michx.	—	*	—	—	—
<i>P. chamaelonche</i> Trin.	—	*	—	—	—
<i>P. chrysopsidifolium</i> Nash	—	*	—	*	—
<i>P. ciliatum</i> Ell.	*	*	—	—	*
<i>P. longifolium</i> Torr.	*	—	*	—	*
<i>P. longiligulatum</i> Nash	—	—	—	—	*
<i>P. rhizomatum</i> Hitchc. and Chase	—	*	*	—	—
<i>P. sp.</i>	*	—	*	—	*
<i>P. thurawi</i> Scribn. and Smith	—	*	—	—	—
<i>P. verrucosum</i> Muhl.	—	—	*	—	—
<i>Paspalum ciliatifolium</i> Michx.	*	*	—	—	*
<i>P. circulare</i> Nash	—	—	—	*	*
<i>P. floridanum</i> Michx.	—	*	*	*	*
<i>P. laeve</i> Michx.	—	—	*	—	—
<i>Pinus palustris</i> Mill. (seedlings)	—	—	*	*	—
<i>P. taeda</i> L. (seedlings)	*	*	*	—	—
<i>Pluchea purpurascens</i> (Swartz) DC.	—	—	—	*	—
<i>Polygala cymosa</i> Walt. [syn. <i>Pilostaxis cymosa</i> (Walt.) Small]	—	—	—	*	—
<i>P. ramosa</i> Ell. [syn. <i>Pilostaxis ramosa</i> (Ell.) Small]	—	—	—	*	—
<i>Proserpinaca palustris</i> L.	—	—	—	—	*
<i>Quercus marilandica</i> Muenchh.	—	—	*	—	—
<i>Rhexia mariana</i> L.	—	—	—	*	—
<i>Rhododendron roseum</i> (Loisel.) Rehd. [syn. <i>Azalea prinophylla</i> (Millais) Small]	*	—	—	—	—
<i>Rhynchospora axillaris</i> (Lam.) Britt.	—	—	*	*	—
<i>R. cymosa</i> Ell.	—	—	*	*	—
<i>R. fascicularis</i> (Michx.) Vahl	—	*	*	—	*
<i>R. gracilentia</i> A. Gray	—	*	—	*	*
<i>R. inexpansa</i> (Michx.) Vahl	—	*	*	*	*
<i>R. schoenoides</i> (Ell.) Britt.	—	—	—	—	*
<i>R. sp.</i>	*	*	—	—	—
<i>R. wrightiana</i> Boeckl.	—	—	—	*	*
<i>Rubus sp.</i>	*	—	—	—	—
<i>Ruellia ciliosa</i> Pursh	—	—	—	*	—
<i>Scleria pauciflora</i> Muhl.	—	—	—	—	*
<i>Scutellaria integrifolia</i> L.	—	—	—	—	*
<i>Sericocarpus bifoliatus</i> (Walt.) Porter	*	*	—	—	*
<i>Smilax auriculata</i> Walt.	*	—	—	—	—
<i>S. pumila</i> Walt.	*	—	—	—	—
<i>Solidago odora</i> Ait.	*	*	*	—	*
<i>Sphagnum</i> spp. (2)	—	—	—	*	*
<i>Spiranthes longilabris</i> Lindl. [syn. <i>Ibidium longilabre</i> (Lindl.) House]	—	—	—	*	*
<i>Stylosanthes biflora</i> (L.) B.S.P.	—	*	*	*	—
<i>Symplocos tinctoria</i> (Garden) L'Hérit.	*	—	—	—	—
<i>Tephrosia ambigua</i> M. A. Curtis [syn. <i>Cracca ambigua</i> (M. A. Curtis) Kuntze]	*	—	*	—	*
<i>T. spicata</i> (Walt.) Torr. and Gray [syn. <i>Cracca spicata</i> (Walt.) Kuntze]	—	*	—	—	—
<i>Tragiola pilosa</i> (Michx.) Small and Pennell	—	—	—	—	*
<i>Trilisa odoratissima</i> (Walt.) Cass.	*	*	*	—	*
<i>Triodia langloisii</i> (Nash) Bush [syn. <i>T. elliottii</i> Bush]	—	—	*	—	*

Species	Stand condition				
	Second growth	Virgin growth		Clear cut	
	Spring	Spring	Fall	Spring	Fall
<i>Utricularia subulata</i> L. [syn. <i>Setiscapella subulata</i> (L.) Barnh.]-----	--	--	--	*	--
<i>Vaccinium virgatum</i> var. <i>tenellum</i> (Ait.) A. Gray [syn. <i>Cyanococcus tenellus</i> (Ait.) Small]-----	*	--	--	--	--
<i>Viola septemloba</i> LeConte-----	--	--	*	--	--
<i>Xyris communis</i> Kunth-----	--	*	--	--	*
<i>X. smalliana</i> Nash-----	*	--	*	--	*
<i>X. torta</i> Kunth-----	--	--	--	*	--

H. Minor Vegetation of Longleaf Pine Cut-Over Lands, Upper Coastal Plain, Ruston Fine Sandy Loam, Washington Parish, La.
(After Pessin (445))

Species	Percent of plant population ¹
<i>Andropogon elliottii</i> Chapm.-----	16
<i>A. scoparius</i> Michx.-----	17
<i>A. tener</i> (Nees) Kunth-----	5
<i>Chrysopsis graminifolia</i> (Michx.) Ell. [syn. <i>Pityopsis graminifolia</i> (Michx.) Nutt.]-----	3
<i>Crotalaria purshii</i> DC.-----	2
<i>Drosera brevifolia</i> Pursh-----	3
<i>Elephantopus tomentosus</i> L.-----	Scattered
<i>Euphorbia corollata</i> L. [syn. <i>Tithymalopsis corollata</i> (L.) Small]-----	do.
<i>Gaylussacia dumosa</i> (Andr.) Torr. and Gray [syn. <i>Lasiococcus dumosus</i> (Andr.) Small]-----	14
<i>Gnaphalium purpureum</i> L.-----	Scattered
<i>Helianthus radula</i> (Pursh) Torr. and Gray-----	10
<i>Hypoxis hirsuta</i> (L.) Coville-----	Scattered
<i>Liatris graminifolia</i> (Walt.) Willd. [syn. <i>Lacinaria graminifolia</i> (Walt.) Kuntze]-----	do.
<i>Myrica cerifera</i> L. [syn. <i>Cerothamnus ceriferus</i> (L.) Small] ² -----	3
<i>Panicum aciculare</i> Desv.-----	18
<i>P. strigosum</i> Muhl.-----	3
<i>Phlox pilosa</i> L.-----	Scattered
<i>Pinguicula lutea</i> Walt.-----	do.
<i>Polygala lutea</i> L. [syn. <i>Pilostaxis lutea</i> (L.) Small]-----	do.
<i>Pteridium latiusculum</i> (Desv.) Maxon [syns. " <i>Pteris aquilina</i> " U. S. authors, not L.; " <i>Pteridium aquilinum</i> " U. S. authors, not (L.) Kuhn]-----	do.
<i>Rhus copallina</i> L. ² -----	do.
<i>Rhynchosia smiplicifolia</i> (Walt.) Wood-----	do.
<i>Sisyrinchium graminoides</i> Bicknell-----	do.
<i>Smilax bona-nox</i> L.-----	do.
<i>Stylosanthes biflora</i> (L.) B. S. P.-----	do.
<i>Tephrosia virginiana</i> (L.) Pers. (syn. <i>Cracca virginiana</i> L.)-----	2
<i>Trilisa odoratissima</i> (Walt.) Cass.-----	Scattered
<i>Vaccinium myrsinites</i> Lam. [syn. <i>Cyanococcus myrsinites</i> (Lam.) Small] ² -----	1
<i>Viola</i> sp. -----	Scattered

¹The 16 species designated "Scattered" compose about 3 percent of the plant population.
²Shrubs.

I. Common Associates of Longleaf Pine in North Carolina (After Wells (603))

LONGLEAF PINE-TURKEY OAK TYPE OF FOREST (THE XERIC COARSE, SAND RIDGE AND INTERRIDGE COMMUNITY)

Dominants:

- Aristida stricta* Michx. (ground cover)
- Pinus palustris* Mill. (upper story)
- Quercus laevis* Walt. (syn. *Q. catesbaei* Michx. (under story)

Subdominants in the pioneer stage:

- Arenaria caroliniana* Walt. [syn. *Alsinopsis caroliniana* (Walt.) Small]
- Asclepias humistrata* Walt.
- Euphorbia ipecacuanhae* L. [syn. *Tithymalopsis ipecacuanhae* (L.) Small]
- Lichens
- Polygonella gracilis* (Nutt.) Meisn.
- Selaginella acanthonota* Underw.
- Stipulicida setacea* Michx.

Subdominants in the middle stage:

- Dionaea muscipula* Ellis (on moist ground)
- Gaylussacia dumosa* (Andr.) Torr. and Gray
- G. frondosa* (L.) Torr. and Gray
- Gentiana porphyrio* J. F. Gmel. [syn. *Dasystephana porphyrio* (J. F. Gmel.) Small]
- Quercus cinerea* Michx.
- Q. stellata* var. *margaretta* (Ashe) Sarg. (syn. *Q. margaretta* Ashe)
- Vaccinium crassifolium* Ait.
- V. virgatum* var. *tenellum* (Ait.) A. Gray (syn. *V. tenellum* Ait.)

Subdominants in the mature stage—a transition to an oak-hickory association:

- Diospyros virginiana* L.
- Potentilla canadensis* L.
- Polycodium candicans*¹ Small
- Quercus falcata* Michx.
- Q. marilandica* Muenchh.
- Rhus copallina* L.
- Sassafras albidum* (Nutt.) Nees [syn. *S. sassafras* (L.) Karst.]
- Tephrosia virginiana* (L.) Pers.
- Vaccinium arboreum* Marsh. [syn. *Batodendron arboreum* (Marsh.) Nutt.]

LONGLEAF PINE ON MOISTER UPLAND SITES (THE MESO-XERIC PINE FOREST)

Dominants:

- Pinus palustris* Mill. or *Pinus taeda* L.

Subdominants:

- Ilex glabra* (L.) A. Gray
- Myrica cerifera* L.
- Quercus falcata* Michx.
- Q. marilandica* Muenchh.
- Q. stellata* Wangenh.

Characteristic herbs:

- Arnica acaulis* (Walt.) B.S.P.
- Baptisia tinctoria* (L.) R. Br.
- Chrysopsis mariana* (L.) Nutt.
- Hieracium venosum* L.
- Parthenium integrifolium* L.

¹Many botanists prefer to regard *Polycodium* as inseparable from *Vaccinium*.

Appendix III

Density Rule for Longleaf or Shortleaf Southern Yellow Pine¹

(a) Dense longleaf or shortleaf yellow pine shall average on either one end or the other of each piece not less than six annual rings per inch, and, in addition, one-third or more summerwood (the darker, harder portions of the annual ring), measured over the third, fourth, and fifth inches of a radial line from the pith. The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood.

(b) Coarse-grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

(c) The radial line shall be representative of the average growth of the cross section. In case of disagreement, two radial lines shall be chosen, and the number of rings per inch and percentage of summerwood shall be taken as the average determined on these lines.

(d) In boxed-heart pieces the measurement shall be made over the third, fourth, and fifth inches from the pith along the radial line.

(e) In material containing the pith, but not a 5-inch radial line, which is less than 2 by 8 inches in section or less than 8 inches in width, that does not show over 16 square inches on the cross section, the inspection shall apply to the second inch from the pith. In larger material that does not show in a 5-inch radial line, the inspection shall apply to the three inches farthest from the pith.

(f) In cases where timbers do not contain the pith and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 inches on an approximate radial line beginning at the edge nearest the pith in timbers over 3 inches in thickness and on the second inch nearest the pith in timbers 3 inches or less in thickness.

¹From standard specifications for structural-wood joist and plank, beams and stringers, and posts and timbers, published by the American Society for Testing Materials, 260 S. Broad Street, Philadelphia, Pa., and approved by the American Standards Association (ASA no. 07-1939). Published in tentative form in 1926 and revised in 1939.

Appendix IV

Strength of Longleaf Pine Wood

Table IV-a.—*Strength and related properties of longleaf pine timber (379)*¹
GREEN—ABOVE FIBER-SATURATION POINT

Item	Place of growth of material tested—										Total or average, all counties and parishes
	Forrest, Miss.	Calcasieu, La.	Nassau, Fla.	Tangipahoa, La.	Washington, La.	Charleston, S. C.	Tammany, La.	Columbia, Fla.			
Trees tested			10	5	9	10	5	5	44		
Rings per inch	17.3	16.1	23.6	16.5	14.4	7.6	13.0	5.1	14		
Summerwood	34	39	43	37	38	40	41	40	39		
Moisture content	30.2	29.0	41.6	63.3	63.8	88.2	70.8	117.4	63		
Specific gravity:											
Based on oven-dry weight and volume at test	.522	.557	.574	.528	.550	.501	.564	.483	.54		
Based on oven-dry weight and volume when oven-dry	.594	.642	.667	.599	.650	.587	.661	.554	.62		
Weight per cubic foot	42	45	51	54	56	59	60	66	55		
Shrinkage from green to oven-dry condition based on green dimensions:											
Volumetric	11.0	12.8	12.2	12.8	12.4	12.9	12.3	10.6	12.2		
Radial	4.8	5.4	5.1	6.0	5.5	4.8	5.5	4.1	5.1		
Tangential	7.5	7.8	6.9	7.6	7.8	7.6	7.7	7.0	7.5		
Static bending:											
Stress at proportional limit (5) ²	4,730	5,810	5,410	5,080	5,650	4,810	5,360	4,430	5,200		
Modulus of rupture (4) ²	7,730	8,930	8,580	8,630	9,400	8,610	9,230	7,770	8,700		
Modulus of elasticity (2) ²	1,406	1,653	1,615	1,662	1,752	1,549	1,717	1,335	1,600		
Work:											
Proportional limit (8) ²	.96	1.08	1.02	.88	1.03	.85	.95	.84	.95		
Maximum load (½) ²	7.0	8.1	7.6	8.1	8.9	10.4	11.2	9.6	8.9		
Total	25.3	29.4	29.3	36.3	34.1	34.8	38.8	30.0	32.4		
Impact bending:											
Stress at proportional limit (3) ²	9,950	10,560	11,150	9,680	11,490	8,600	10,400	8,100	10,100		
Work to proportional limit (4) ²	3.4	3.3	3.6	3.0	3.8	2.4	3.1	2.7	3.2		
Height of drop causing complete failure—50-lb. hammer (—½) ²	31	31	33	35	39	36	40	34	35		
Compression parallel to grain:											
Stress at proportional limit (5) ²	3,540	3,990	3,860	3,470	3,880	2,780	3,390	2,370	3,430		
Maximum crushing strength (6) ²	4,020	4,550	4,340	4,280	4,620	4,130	4,710	3,640	4,300		
Compression perpendicular to grain:											
Stress at proportional limit (5½) ²	513	628	576	491	707	531	714	547	590		
Hardness; load required to embed a 0.444-inch ball to ½ its diameter:											
End (4) ²	466	524	542	574	597	548	597	562	550		
Side (2½) ²	526	595	602	512	664	574	641	562	590		
Shear parallel to grain; maximum shearing strength (3) ²	1,034	1,062	1,066	1,006	1,150	955	992	996	1,040		
Cleavage; load to cause splitting	172	174	177	184	222	238	248	254	210		
Tension perpendicular to grain; maximum tensile strength (1½) ²											
Lbs. per sq. in.	274	298	274	269	324	382	428	448	330		

See footnote at end of table.

Table IV-a.—Strength and related properties of longleaf pine timber (379)¹—Continued

DRY—ADJUSTED TO 12-PERCENT MOISTURE CONTENT										
Trees tested	Number	1	2	3	4	5	6	7	8	9
Moisture content	Percent									
Specific gravity: Based on oven-dry weight and volume at test		11.6	12.8	6.9	12.0	5.62	6.27	13.2	5.57	11.7
Weight per cubic foot		.549	.574	.648	.562	.627	.627	.557	.626	.529
Static bending:										
Stress at proportional limit (5) ²	Lbs. per sq. in.	8,520	9,010	13,400	10,040	14,120	7,600	10,010	7,040	9,300
Modulus of rupture (4) ²	do.	12,770	13,800	18,540	14,300	19,360	14,300	16,670	12,990	14,700
Modulus of elasticity (2) ²	M lbs. per sq. in.	1,694	1,861	2,422	2,022	2,488	1,920	2,181	1,556	1,990
Work:										
Proportional limit (8) ²	In.-lbs. per cu. in.	2.43	2.53	4.20	2.76	4.47	1.68	2.59	1.79	2.44
Maximum load (1½) ²	do.	9.1	10.3	11.8	12.4	11.8	13.9	14.3	12.5	11.8
Total	do.	14.4	19.5	24.6	22.2	25.6	21.5	22.0	18.2	21.9
Impact bending:										
Stress at proportional limit (5) ²	Lbs. per sq. in.	15,030	14,890	18,620	15,300	16,310	14,690	17,510	13,590	15,400
Work to proportional limit (4) ²	In.-lbs. per cu. in.	6.2	5.7	7.5	6.2	6.5	5.6	7.0	5.4	6.1
Height of drop causing complete failure—50-lb. hammer (—½) ²	In.	28	29	34	31	35	37	37	35	34
Compression parallel to grain:										
Stress at proportional limit (5) ²	Lbs. per sq. in.	5,740	5,680	9,030	6,040	10,400	4,850	7,100	4,770	6,150
Maximum crushing strength (6) ²	do.	8,180	7,990	12,720	8,140	13,210	7,420	9,510	7,350	8,440
Compression perpendicular to grain:										
Stress at proportional limit (5½) ²	do.	1,435	1,492	1,920	1,413	1,740	887	1,239	1,148	1,190
Hardness; load required to embed a 0.444-inch ball to ½ its diameter:										
End (4) ²	Pounds	988	1,010	1,350	924	1,194	770	973	890	920
Side (2½) ²	do.	850	906	1,220	798	1,010	798	992	812	870
Shear parallel to grain; maximum shearing strength (3) ²	Lbs. per sq. in.	1,426	1,373	1,886	1,688	1,618	1,346	1,760	1,554	1,500
Cleavage; load to cause splitting	Lbs. per in. of width	182	196	246	210	312	334	348	336	270
Tension perpendicular to grain; maximum tensile strength (1½) ²										
	Lbs. per sq. in.	352	355	418	374	—	556	608	609	470

¹The material tested consisted of small specimens of clear wood from trees botanically identified as longleaf pine. Formulae for computing strength values, methods used, and the significance of the test results are given in the original publication (379). The average specific gravity of 806 botanical specimens used in these tests was 0.55, whereas the average for 5,396 commercial specimens was 0.52 (0.57 for heartwood and 0.48 for sapwood) with a probable variation of ± 0.3 percent. The moisture content of green wood from 18 trees averaged 34 percent in the heartwood and 99 percent in the sapwood portion.

²Average percent increase (or decrease) in value effected by lowering (or raising) the moisture content 1 percent.

Table IV-b.—Approximate relations of specific gravity to strength properties for hardwood and softwood species tested green and air-dry at about 12-percent moisture content, and approximate percentage corrections for longleaf pine¹

Property	Strength formulae for all woods tested		Percentage correction for longleaf pine		
	Green	Air-dry	Green	Air-dry	
Static bending:					
Fiber stress at proportional limit	Lbs. per sq. in._____	10200G ^{1.25}	16700G ^{1.25}	—	—
Modulus of rupture_____	do. _____	17600G ^{1.25}	25700G ^{1.25}	97	107
Work to maximum load_____	Inch-lbs. per cu. in.—	35.6G ^{1.75}	32.4G ^{1.75}	61	95
Total work_____	do. _____	103G ²	72.7G ²	82	96
Modulus of elasticity_____	1,000 lbs. per sq. in.	2360G	2800G	116	117
Impact bending:					
Fiber stress at proportional limit	Lbs. per sq. in._____	23700G ^{1.25}	31200G ^{1.25}	—	—
Modulus of elasticity_____	1,000 lbs. per sq. in.	2940G	3380G	108	110
Height of drop_____	Inches _____	114G ^{1.75}	94.6G ^{1.75}	75	96
Compression parallel to grain:					
Fiber stress at proportional limit	Lbs. per sq. in._____	5250G	8750G	—	—
Maximum crushing strength_____	do. _____	6730G	12200G	114	121
Modulus of elasticity_____	1,000 lbs. per sq. in.	2910G	3380G	118	109
Compression perpendicular to grain:					
Fiber stress at proportional limit	Lbs. per sq. in._____	3000G ^{2.25}	4630G ^{2.25}	—	—
Hardness:					
End _____	Pounds _____	3740G ^{2.25}	4800G ^{2.25}	56	66
Radial _____	do. _____	3380G ^{2.25}	3720G ^{2.25}	66	73
Tangential _____	do. _____	3460G ^{2.25}	3820G ^{2.25}	68	80

¹G represents specific gravity, oven-dry, based on volume at moisture condition indicated. The green longleaf pine tested came from Florida, Mississippi, and Louisiana. All the air-dried longleaf came from Louisiana. It should not be inferred that, if the exact specific gravity is known, strength values can be computed with great accuracy by these formulae, because other factors, such as defects and moisture, cause considerable variation in strength (379 and 410).

Table IV-c.—Factors for converting strength values established for longleaf pine of a definite moisture content to corresponding values for different moisture contents¹ (553)

MAXIMUM CRUSHING STRENGTH IN COMPRESSION PARALLEL TO GRAIN												
TO moisture percent	FROM moisture percent—											
	2	4	6	8	10	12	14	16	18	20	² 20.3	22
2	1	1.120	1.265	1.425	1.605	1.81	2.05	2.32	2.65	3.05	3.12	3.60
4	.894	1	1.13	1.275	1.435	1.62	1.83	2.07	2.37	2.73	2.79	3.22
6	.790	.885	1	1.125	1.27	1.43	1.62	1.835	2.09	2.45	2.47	2.84
8	.702	.785	.888	1	1.125	1.27	1.44	1.63	1.86	2.14	2.19	2.53
10	.623	.698	.788	.887	1	1.13	1.28	1.445	1.65	1.90	1.945	2.24
12	.552	.618	.699	.786	.885	1	1.13	1.28	1.46	1.685	1.725	1.99
14	.488	.546	.617	.695	.783	.884	1	1.13	1.29	1.49	1.52	1.755
16	.431	.482	.545	.614	.691	.781	.884	1	1.14	1.315	1.345	1.55
18	.377	.422	.478	.538	.605	.684	.774	.876	1	1.15	1.18	1.36
20	.328	.367	.414	.467	.526	.593	.672	.760	.867	1	1.02	1.18
² 20.3	.320	.359	.406	.457	.514	.581	.657	.744	.849	.978	1	1.155
22	.278	.311	.351	.396	.445	.503	.569	.645	.735	.848	.866	1

See notes at end of table, p. 285.

Table IV-c.—Factors for converting strength values established for longleaf pine of a definite moisture content to corresponding values for different moisture contents¹ (553)—Continued

MODULUS OF RUPTURE IN BENDING													
TO moisture percent	FROM moisture percent—												
	4	6	8	10	12	14	16	18	20	22	24	225	26
4	1	1.14	1.30	1.45	1.60	1.73	1.87	1.99	2.11	2.22	2.33	2.39	2.45
6	.877	1	1.14	1.27	1.41	1.52	1.64	1.75	1.885	1.945	2.04	2.10	2.15
8	.770	.877	1	1.115	1.235	1.335	1.44	1.535	1.625	1.71	1.79	1.845	1.885
10	.690	.786	.896	1	1.105	1.195	1.29	1.375	1.445	1.53	1.605	1.65	1.69
12	.624	.711	.811	.904	1	1.08	1.165	1.24	1.32	1.385	1.455	1.495	1.53
14	.577	.658	.750	.836	.925	1	1.08	1.15	1.22	1.28	1.345	1.38	1.415
16	.535	.610	.695	.775	.857	.927	1	1.065	1.13	1.185	1.245	1.28	1.31
18	.502	.572	.653	.728	.804	.870	.938	1	1.06	1.115	1.17	1.20	1.23
20	.474	.540	.616	.687	.759	.821	.885	.935	1	1.05	1.105	1.135	1.16
22	.451	.514	.586	.654	.723	.781	.843	.898	.951	1	1.05	1.08	1.105
24	.429	.490	.558	.623	.689	.745	.804	.856	.906	.954	1	1.03	1.05
225	.418	.476	.543	.606	.670	.725	.782	.832	.882	.927	.973	1	1.025
26	.408	.466	.531	.592	.655	.708	.764	.814	.862	.906	.951	.978	1

MODULUS OF ELASTICITY IN BENDING													
TO moisture percent	FROM moisture percent—												
	2	4	6	8	10	12	14	16	217.5	18	20	22	24
2	1	1.09	1.20	1.31	1.42	1.51	1.59	1.65	1.69	1.70	1.75	1.78	1.82
4	.92	1	1.11	1.20	1.31	1.39	1.46	1.52	1.55	1.57	1.61	1.63	1.67
6	.831	.903	1	1.09	1.18	1.26	1.32	1.37	1.40	1.41	1.45	1.47	1.57
8	.765	.830	.92	1	1.08	1.16	1.21	1.26	1.29	1.30	1.33	1.36	1.39
10	.705	.766	.848	.922	1	1.06	1.12	1.16	1.19	1.20	1.23	1.25	1.28
12	.661	.720	.796	.865	.938	1	1.05	1.09	1.12	1.13	1.15	1.18	1.20
14	.630	.684	.753	.824	.894	.952	1	1.04	1.06	1.07	1.10	1.12	1.15
16	.607	.659	.730	.794	.860	.917	.964	1	1.02	1.03	1.06	1.08	1.10
217.5	.592	.645	.714	.776	.842	.897	.944	.977	1	1.01	1.03	1.05	1.08
18	.588	.640	.708	.770	.835	.889	.935	.970	.992	1	1.03	1.05	1.07
20	.573	.623	.690	.750	.813	.866	.910	.946	.966	.975	1	1.02	1.04
22	.564	.612	.678	.737	.799	.851	.895	.928	.950	.957	.983	1	1.02
24	.550	.598	.662	.720	.780	.832	.875	.908	.928	.935	.960	.977	1

STRESS AT ELASTIC LIMIT IN BENDING													
TO moisture percent	FROM moisture percent—												
	2	4	6	8	10	12	14	16	18	20	22	24	226
2	1	1.13	1.31	1.53	1.75	1.99	2.20	2.39	2.54	2.70	2.85	2.99	3.14
4	.882	1	1.15	1.35	1.54	1.75	1.94	2.11	2.25	2.39	2.52	2.64	2.77
6	.767	.867	1	1.17	1.34	1.52	1.69	1.83	1.95	2.07	2.18	2.29	2.41
8	.656	.742	.856	1	1.15	1.30	1.44	1.57	1.67	1.77	1.87	1.96	2.06
10	.572	.648	.746	.882	1	1.13	1.26	1.37	1.45	1.54	1.63	1.71	1.80
12	.503	.570	.657	.768	.881	1	1.11	1.20	1.28	1.36	1.44	1.51	1.58
14	.455	.515	.594	.694	.795	.904	1	1.09	1.16	1.23	1.30	1.36	1.43
16	.419	.475	.547	.639	.733	.832	.921	1	1.07	1.13	1.19	1.25	1.32
18	.393	.445	.513	.600	.688	.781	.865	.938	1	1.06	1.12	1.17	1.24
20	.370	.420	.485	.565	.648	.735	.814	.884	.941	1	1.05	1.11	1.16
22	.351	.397	.458	.535	.614	.697	.771	.838	.893	.948	1	1.05	1.10
24	.335	.379	.437	.510	.585	.665	.735	.799	.851	.904	.954	1	1.05
226	.318	.361	.415	.486	.556	.633	.700	.760	.810	.860	.908	.951	1

¹Resistance to crushing strength as influenced by moisture and specific gravity in longleaf pine wood may be expressed by the following equation: $C = G(22.1 p^2 - 1335 p + 25610)$ where C is crushing strength in pounds per square inch, G is specific gravity of dry wood, and p is percentage of moisture. The factors above are computed from a sheath of harmonized curves of this relationship.

²Green.

Appendix V

Value of Southern Pines for Piece Products

As the following tables indicate, some trees are worth more as piles or poles than as sawlogs or pulpwood. The differential often warrants segregation and special sale.

Poles, piles, and ties require special measurement. The wood content may be estimated for records of forest growth and yield, but the dimensions of pieces sold must meet exacting specifications.

Industrial committees issue detailed specifications like those in Table V-b for the guidance of pole and pile cutters. The volumes included in different classes of poles are shown in Table V-c. Instructions issued with specifications cover special requirements, including allowable defects. For instance, knots are limited to a certain size and concentration for poles of a given class. Defects are defined and methods of measuring sweep and crook are illustrated (7).

Standard dimensions used in the commercial classification of poles (Table V-a) include minimum circumferences at two points. Because these are not the dimensions used in scaling logs, equivalent butt and top diameters are shown in Table V-d, permitting direct comparison with other products. For example, the second pole listed in Table V-d could be cut into logs scaling 80 board feet (Table V-g). The value of this tree at \$5 per M stumpage would be 40 cents (Table V-g) as against perhaps only 36 cents as a pole (Table V-d). With a market for ties, this same tree might bring 45 cents (Table V-f). Piles often bring still higher prices (Table V-e), but this particular tree will not qualify (Table V-b), being too small at the top for a pile less than 40 feet long.

Table V-a.—Standard dimensions for southern pine poles¹

Length of pole (feet)	Ground-line distance from butt ² (feet)	Class of creosoted pole ¹						
		1	2	3	4	5	6	7
		Minimum top circumference (inches)—						
		27	25	23	21	19	17	15
		Minimum circumference at 6 feet from butt (inches)—						
16	3½	---	---	---	---	21.5	19.5	18.0
18	3½	---	---	26.5	24.5	22.5	21.0	19.0
20	4	31.5	29.5	27.5	25.5	23.5	22.0	20.0
22	4	33.0	31.0	29.0	26.5	24.5	23.0	21.0
25	5	34.5	32.5	30.0	28.0	26.0	24.0	22.0
30	5½	37.5	35.0	32.5	30.0	28.0	26.0	24.0
35	6	40.0	37.5	35.0	32.0	30.0	27.5	25.5
40	6	42.0	39.5	37.0	34.0	31.5	29.0	27.0
45	6½	44.0	41.5	38.5	36.0	33.0	30.5	28.5
50	7	46.0	43.0	40.0	37.5	34.5	32.0	29.5
55	7½	47.5	44.5	41.5	39.0	36.0	33.5	---
60	8	49.5	46.0	43.0	40.0	37.0	34.5	---
65	8½	51.0	47.5	44.5	41.5	38.5	---	---
70	9	52.5	49.0	46.0	42.5	39.5	---	---
75	9½	54.0	50.5	47.0	44.0	---	---	---
80	10	55.0	51.5	48.5	45.0	---	---	---
85	10½	56.5	53.0	49.5	---	---	---	---
90	11	57.5	54.0	50.5	---	---	---	---

¹Specifications of the American Standards Association. There is no butt requirement specified for classes 8, 9, and 10; minimum top circumferences, however, are 18, 15, and 12 inches, respectively.

²The figures in this column may be used to apply specification requirements relating to scars, straightness, etc.

Table V-b.—Standard dimensions for southern pine piles¹

Use and specified diameter	Length of pile (feet)—				
	Under 40	40 to 50	51 to 70	71 to 90	Over 90
	Inches	Inches	Inches	Inches	Inches
Class A (for railway bridges):					
Diameter 3 feet from butt:					
Minimum _____	14	14	14	14	14
Maximum _____	18	18	18	20	20
Minimum diameter of tip _____	10	9	8	7	6
Class B (for highway bridges):					
Diameter 3 feet from butt:					
Minimum _____	12	12	13	13	13
Maximum _____	20	20	20	20	20
Minimum diameter of tip _____	8	7	7	6	5
Class C (for sundry temporary work):					
Diameter 3 feet from butt:					
Minimum _____	12	12	12	12	12
Maximum _____	20	20	20	20	20
Minimum diameter of tip _____	8	6	6	6	5

¹Specifications of the American Society for Testing Materials. These may be used for Douglas-fir as well as southern pine.

Table V-c.—Volumes of poles of different classes treated with preservatives as specified by the Rural Electrification Administration¹

Length (feet)	Class of pole—						
	1	2	3	4	5	6	7
	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet
25	18.00	14.75	12.25	10.38	8.88	7.63	6.25
30	23.25	19.63	16.75	14.25	12.00	10.00	8.26
35	28.50	24.38	21.00	18.25	15.63	13.50	11.75
40	34.25	29.50	25.50	22.13	19.25	16.75	14.63
45	40.38	34.75	30.25	26.25	23.13	20.25	17.75
50	47.00	40.25	35.00	30.63	27.13	24.13	21.25
55	54.13	46.63	40.00	35.13	31.25	28.38	-----
60	62.75	53.50	45.62	39.75	35.50	32.75	-----
65	73.00	60.75	51.13	44.63	40.63	-----	-----
70	84.00	68.75	57.13	49.63	45.25	-----	-----

¹Poles to be treated with creosote under pressure may be either air dried or steam seasoned. Those which are partially air dried and then steamed are preferred.

Table V-d.—Dimensions and values of poles of different sizes and classes¹

Pole ² class	Minimum diameter		Length	Value f.o.b. car	Stumpage value at percent of f.o.b. car prices		
	Butt	Top			30%	40%	50%
	Inches	Inches		Dollars	Dollars	Dollars	Dollars
5	10 1/4	6 1/8	30	1.05	0.32	0.42	0.52
4	*10 3/4	7		1.20	.36	.48	.60
6	10	5 3/4		1.20	.36	.48	.60
5	10 3/4	6 1/8	35	1.75	.52	.70	.88
4	11 1/2	7		2.10	.63	.84	1.05
3	12-2/5	7 2/3		2.50	.75	1.00	1.25
2	*13	8 1/4	40	3.00	.90	1.20	1.50
4	12	7		2.75	.82	1.10	1.38
3	13	7 2/3		3.00	.90	1.20	1.50
2	*13-9/10	8 1/4	45	3.75	1.12	1.50	1.88
3	13 1/2	7 2/3		4.75	1.42	1.90	2.38
2	*14 1/2	8 1/4		5.25	1.58	2.10	2.62
4	12-2/5	7	50	4.75	1.42	1.90	2.38
3	14	7 2/3		6.00	1.80	2.40	3.00
2	*15	8 1/4		7.20	2.16	2.88	3.60
4	13 1/2	7	55	5.50	1.65	2.20	2.75
3	14 1/2	7 2/3		7.00	2.10	2.80	3.50
2	*15 1/2	8 1/4		8.50	2.55	3.40	4.25

See notes at end of table, p. 288.

Table V-d.—Dimensions and values of poles of different sizes and classes¹—Continued

Pole ² class	Minimum diameter		Length	Value f.o.b. car	Stumpage value at percent of f.o.b. car prices		
	Butt	Top			30%	40%	50%
	Inches	Inches	Feet	Dollars	Dollars	Dollars	Dollars
4	14	7	60	7.00	2.10	2.80	3.50
3	15	7 $\frac{3}{4}$		10.00	3.00	4.00	5.00
2	*16	8 $\frac{1}{4}$		12.00	3.60	4.80	6.00
4	14 $\frac{1}{2}$	7	65	9.60	2.88	3.84	4.80
3	15 $\frac{1}{2}$	7 $\frac{3}{4}$		12.00	3.60	4.80	6.00
2	*16 $\frac{1}{2}$	8 $\frac{1}{4}$		15.00	4.50	6.00	7.50
4	15 $\frac{3}{4}$	7	70	10.80	3.24	4.32	5.40
3	16	7 $\frac{3}{4}$		13.20	3.96	5.28	6.60
2	*17	8 $\frac{1}{4}$		18.00	5.40	7.20	9.00
4	15 $\frac{1}{2}$	7	75	13.00	3.90	5.20	6.50
2	*17 $\frac{1}{4}$	8 $\frac{1}{4}$		23.00	6.90	9.20	11.50

¹Asterisks designate poles whose value for lumber or cheaper products is shown in Tables V-g and V-h. Comparisons are based on f.o.b. car prices, December 1942, Jacksonville, Fla. (274).

²Poles should be smoothly hand trimmed or machine turned. The depth of the machine cut should be kept at a practical minimum except at knot whorls and other local irregularities on the pole surface. The circumference at intermediate points should not be reduced more than one inch.

Table V-e.—Dimensions and values of piles of different sizes and classes¹

Minimum diameter (inches)		Length	Value f.o.b. car	Stumpage value at percent of f.o.b. car prices		
Butt	Top			30%	40%	50%
		Feet	Dollars	Dollars	Dollars	Dollars
12 $\frac{1}{2}$	8	30	3.00	0.90	1.20	1.50
12 $\frac{1}{2}$		35	3.50	1.05	1.40	1.75
13		40	4.80	1.44	1.92	2.40
13	7	45	5.40	1.62	2.16	2.70
13 $\frac{1}{2}$		50	7.00	2.10	2.80	3.50
13 $\frac{1}{2}$		55	8.25	2.48	3.30	4.12
14	6	60	10.80	3.24	4.32	5.40
14		70	16.10	4.83	6.44	8.05

¹Based on f.o.b. car prices, December 1942, Jacksonville, Fla. (274).

Table V-f.—Number and value of ties contained in trees meeting specifications for piles or poles¹

Piles or poles			8 $\frac{1}{2}$ -foot ties by size and value f.o.b. car ²				Stumpage value at percent of f.o.b. car price			
Minimum butt diame- ter (inches)	Minimum top diameter	Length	7"x9" \$1.10	7"x8" \$0.95	6"x8" \$0.80	6"x7" \$0.70	Total	30%	40%	50%
	Inches	Feet	Number	Number	Number	Number	Dollars	Dollars	Dollars	Dollars
12 $\frac{1}{2}$	8	30	1	0	1	1	2.60	0.78	1.04	1.30
10 $\frac{3}{4}$	7	30	0	0	1	1	1.50	.45	.60	.75
12 $\frac{1}{2}$	8	35	1	1	0	1	2.75	.82	1.10	1.38
13	8 $\frac{1}{4}$	35	1	1	0	1	2.75	.82	1.10	1.38
13	8	40	1	1	1	1	3.55	1.06	1.42	1.78
14 $\frac{1}{2}$	8 $\frac{1}{4}$	45	2	1	1	1	4.65	1.40	1.86	2.32
13 $\frac{1}{2}$	7	50	2	0	1	1	3.70	1.11	1.48	1.85
15	8 $\frac{1}{4}$	50	2	1	1	1	4.65	1.40	1.86	2.32
13 $\frac{1}{2}$	7	55	2	1	0	1	3.85	1.16	1.54	1.92
15 $\frac{1}{2}$	8 $\frac{1}{4}$	55	3	1	0	1	4.95	1.48	1.98	2.48
14	6	60	2	1	0	1	3.85	1.16	1.54	1.92
16	8 $\frac{1}{4}$	60	3	1	1	1	5.75	1.72	2.30	2.88
14	6	65	2	1	1	1	4.65	1.40	1.86	2.32
16 $\frac{1}{2}$	8 $\frac{1}{4}$	65	4	2	0	1	7.00	2.10	2.80	3.50
14	6	70	2	1	1	1	4.65	1.40	1.86	2.32
17	8 $\frac{1}{4}$	70	4	2	0	1	7.00	2.10	2.80	3.50
17 $\frac{1}{4}$	8 $\frac{1}{4}$	75	4	2	0	1	7.00	2.10	2.80	3.50

¹Includes all piles in Table V-e, but only those poles marked with an asterisk in Table V-d. Based on f.o.b. car prices, December 1942, Jacksonville, Fla. (274).

²Recently some roads have used ties merely slabbed on two sides to the standard 6- or 7-inch thickness.

Table V-g.—*Number, volume, and value of sawlogs contained in trees meeting specifications for piles or poles¹*

Piles or poles			16-foot logs per tree	Volume per tree	Stumpage value per M board feet at—		
Minimum butt diame- ter (inches)	Minimum top diameter	Length			\$5	\$10	\$15
	<i>Inches</i>	<i>Feet</i>	<i>Number</i>	<i>Board feet</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
12½	8	30	2	105	0.52	1.05	1.57
10¾	7	30		80	.40	.80	1.20
12½	8	35		105	.52	1.05	1.57
13	8¼	35	2½	105	.52	1.05	1.57
13	8	40		145	.72	1.45	2.17
13-9/10	8¼	40		145	.72	1.45	2.17
13	8	45	3	170	.85	1.70	2.55
14½	8¼	45		200	1.00	2.00	3.00
13½	7	50		160	.80	1.60	2.40
15	8¼	50	3½	200	1.00	2.00	3.00
13½	7	55		180	.90	1.80	2.70
15½	8¼	55		260	1.30	2.60	3.90
14	6	60	4	210	1.05	2.10	3.15
16	8¼	60		335	1.67	3.35	5.02
14	6	65		220	1.10	2.20	3.30
16½	8¼	65	4½	335	1.67	3.35	5.02
14	6	70		220	1.10	2.20	3.30
17	8¼	70		420	2.10	4.20	6.30
17¼	8¼	75		420	2.10	4.20	6.30

¹Logs counted to nearest one-half standard log and scaled to the nearest inch of diameter by the International ¼-inch log rule. All piles in Table V-e, and some of the poles from Table V-d (see asterisks), are included (274).

Table V-h.—*Number and diameter of 5-foot sticks and units of pulpwood contained in trees meeting specifications for piles and poles¹*

Piles or poles			Sticks	Average stick diameter	Units ²	Stumpage value per unit at—		
Minimum butt diame- ter (inches)	Minimum top diameter	Length				\$1.00	\$1.50	\$2.00
	<i>Inches</i>	<i>Feet</i>	<i>Number</i>	<i>Inches</i>	<i>Number</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
12½	8	30	6	10.25	0.15	0.15	0.22	0.30
10¾	7	30	6	8.875	.115	.11	.17	.23
12½	8	35	7	10.0	.167	.17	.25	.33
13	8¼	35	7	10.5	.184	.18	.28	.37
13	8	40	8	10.5	.2078	.21	.31	.42
13-9/10	8¼	40	8	10.625	.2126	.21	.32	.43
13	8	45	9	10.5	.2337	.23	.35	.47
14½	8¼	45	9	11.375	.2717	.27	.41	.54
13½	7	50	10	10.25	.2484	.25	.37	.50
15	8¼	50	10	11.625	.3137	.31	.47	.63
13½	6	55	11	10.25	.2733	.27	.41	.55
15½	8¼	55	11	11.875	.3591	.36	.54	.72
14	6	60	12	10.0	.2857	.29	.43	.57
16	8¼	60	12	12.125	.4138	.41	.62	.83
14	6	65	13	10.0	.3095	.31	.46	.62
16½	8¼	65	13	12.375	.4643	.46	.70	.93
14	6	70	14	10.0	.3333	.33	.50	.67
17	8¼	70	14	12.625	.5148	.51	.77	1.03
17¼	8¼	75	15	12.75	.5746	.57	.86	1.15

¹Figures include the turpented butt portion of trees (274).

²A unit is a stack 4 by 5 by 8 feet, or equivalent to 1.25 standard cords.

Table VI-a.—Stand table for second-growth longleaf pine in normal stands (183)
AVERAGE SITE INDEX—71 FEET

Age (years)	Average diameter, breast high Inches	Trees per acre in and above diameter class of—									
		2 inches	4 inches	6 inches	8 inches	10 inches	12 inches	14 inches	16 inches	18 inches	20 inches
		Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
15	2.8	1,595	383	37							
20	3.8	1,140	513	114	10						
25	4.8	910	582	228	38	3					
30	5.6	720	556	303	87	13					
35	6.3	595	499	321	119	25	3				
40	6.9	510	454	326	153	42	7				
45	7.5	455	420	333	187	68	14	2			
50	8.0	410	386	321	201	82	21	3			
55	8.5	375	361	308	211	102	31	6			
60	8.9	350	337	298	214	112	39	8	1		
65	9.3	320	312	283	216	122	48	13	2		
70	9.7	300	296	275	217	136	60	18	4		
75	10.1	280	276	262	220	147	73	25	6		
80	10.4	265	264	248	211	147	77	29	8	1	
85	10.8	250	249	239	209	154	86	35	10	2	
90	11.1	240	240	232	206	157	94	41	13	3	
95	11.4	230	230	223	200	158	97	46	16	4	
100	11.8	220	220	215	198	160	107	56	21	6	1

D.b.h. of average tree in stand (inches)	ALL SITES											
	Trees in and above diameter class of—											
	2 inches	4 inches	6 inches	8 inches	10 inches	12 inches	14 inches	16 inches	18 inches	20 inches	22 inches	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
3	100	28	3									
4	100	49	13	1								
5	100	67	28	6								
6	100	81	49	17	3							
7	100	90	66	32	9	2						
8	100	94	78	49	20	5	1					
9	100	97	86	63	34	12	3					
10	100	98	92	76	49	23	8	2				
11	100	99	95	84	63	37	16	5	1			
12	100	99	97	90	74	50	26	10	3	1		
13	---	100	98	93	81	62	38	18	7	2		
14	---	100	99	96	88	72	51	29	13	4	1	

Table VI-b.—*Number of trees per acre in fully stocked second-growth stands of longleaf pine, and frequency of trees above given sizes on various sites¹*

TREES 2 INCHES OR MORE D.B.H.

Age (years)	Site index, feet—						
	40	50	60	70	80	90	100
	<i>Trees per acre</i>						
15	2,145	1,985	1,800	1,610	1,450	1,260	1,090
20	1,550	1,410	1,290	1,150	1,050	910	790
25	1,220	1,120	1,020	920	820	720	630
30	990	900	815	730	655	575	500
35	810	740	670	600	540	465	415
40	690	625	575	515	465	405	355
45	615	555	515	460	415	365	315
50	560	505	465	415	375	330	285
55	510	465	425	380	345	300	260
60	470	430	395	355	315	275	240
65	440	400	365	325	295	255	225
70	410	375	345	305	270	240	205
75	385	355	320	285	255	220	195
80	365	335	305	270	240	210	185
85	345	315	285	255	230	200	175
90	325	300	275	245	215	190	165
95	310	285	260	235	210	180	160
100	295	275	250	225	200	175	155

TREES 4 INCHES OR MORE D.B.H.

15	50	155	205	250	300	345	405	420
20	215	295	400	500	580	580	555	520
25	265	385	500	550	580	550	500	465
30	300	430	540	540	530	495	445	405
35	330	440	550	495	475	425	385	350
40	345	435	475	450	420	380	336	309
45	360	425	440	415	385	345	305	275
50	360	410	410	380	355	320	282	250
55	355	390	385	355	330	295	260	230
60	345	365	360	330	310	275	240	210
65	335	350	340	310	290	255	225	195
70	325	335	320	295	270	240	210	180
75	315	320	305	280	255	225	200	170
80	300	305	290	265	240	215	185	160
85	290	295	275	255	230	200	175	150
90	280	280	265	240	220	190	165	145
95	270	270	255	230	210	185	160	140
100	265	260	245	225	200	175	150	130

TREES 7 INCHES OR MORE D.B.H.

15				3	6	13	23	31
20			15	35	70	110	140	170
25			63	112	150	211	258	273
30	10	35	110	170	220	255	270	275
35	22	61	148	208	253	266	268	257
40	35	100	185	235	265	265	255	240
45	50	136	213	249	264	261	245	230
50	65	160	230	255	260	255	235	220
55	84	175	234	253	254	242	224	209
60	105	185	235	245	245	230	215	200
65	116	192	233	240	238	222	206	189
70	125	195	230	235	230	215	195	180
75	133	199	226	227	222	209	189	170
80	140	200	220	220	215	195	180	160
85	145	200	216	214	207	190	174	153
90	150	200	210	210	200	185	165	145
95	153	196	206	201	193	178	161	137
100	155	190	200	200	185	170	155	130

See note at end of table, p. 292.

LONGLEAF PINE

Table VI-b.—Number of trees per acre in fully stocked second-growth stands of longleaf pine, and frequency of trees above given sizes on various sites¹—Continued

DOMINANT TREES								
Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Trees per acre</i>							
15	730	685	650	605	560	495	440	390
20	620	590	560	525	485	445	400	350
25	500	480	460	435	405	370	335	300
30	425	410	390	370	345	315	285	255
35	370	355	340	320	300	275	250	220
40	325	315	305	285	260	240	220	195
45	295	285	275	265	245	220	200	175
50	275	265	255	245	225	205	185	165
55	255	250	240	230	210	195	175	155
60	240	235	225	215	200	185	165	145
65	225	220	215	205	190	175	160	140
70	215	210	200	195	180	165	150	135
75	210	200	195	185	175	160	145	130
80	195	190	185	180	170	155	140	125
85	190	185	180	170	160	150	135	120
90	185	180	175	170	155	145	130	115
95	180	175	170	165	150	140	125	110
100	175	170	165	160	145	135	125	110

¹(561, Tables 68, 74, 83, and 92).

Table VI-c.—Square-foot basal area per acre, by breast-height diameters, for second-growth longleaf pine in fully stocked stands on various sites¹

TREES 2 INCHES OR MORE D.B.H.								
Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Basal area in square feet</i>							
15	35	48	60	69	77	83	87	91
20	48	64	79	92	102	109	114	118
25	54	72	89	104	114	123	128	132
30	58	78	97	113	124	134	140	144
35	63	83	103	120	133	143	150	154
40	66	88	108	127	140	150	158	162
45	69	92	113	133	147	157	165	170
50	72	95	118	138	152	162	170	176
55	74	98	121	141	156	167	175	181
60	76	100	124	145	160	170	179	185
65	77	102	126	148	163	174	182	189
70	79	104	128	150	166	176	185	192
75	80	105	130	152	168	179	187	194
80	80	106	131	153	169	180	189	196
85	81	107	132	154	171	182	191	197
90	82	108	133	155	172	184	192	198
95	82	108	134	156	173	185	193	199
100	82	109	135	157	173	186	194	200

See notes at end of table, p. 293.

Table VI-c.—*Square-foot basal area per acre, by breast-height diameters, for second-growth longleaf pine in fully stocked stands on various sites¹—Continued*

TREES 4 INCHES OR MORE D.B.H.

Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
15	4	6	22	29	41	52	65	72
20	12	35	55	75	89	98	106	112
25	29	54	74	92	107	116	124	130
30	41	65	87	105	120	130	137	144
35	49	74	96	115	131	141	148	154
40	56	81	104	124	139	149	157	162
45	61	87	110	132	146	156	164	170
50	65	91	116	137	152	162	170	176
55	68	95	120	141	157	167	175	181
60	71	98	123	145	160	171	179	185
65	73	101	126	148	163	174	182	189
70	75	103	128	150	166	176	184	192
75	77	104	130	152	168	179	187	194
80	78	106	131	153	169	181	189	196
85	79	107	133	155	171	182	190	197
90	80	107	134	156	172	184	192	198
95	81	108	134	157	173	185	193	199
100	81	108	135	157	173	186	194	200

TREES 7 INCHES OR MORE D.B.H.

15				1	2	4	8	11
20		1	6	13	23	35	49	60
25		7	19	34	51	67	84	100
30	4	14	34	54	78	99	114	124
35	8	23	49	74	100	119	130	140
40	13	34	65	91	116	132	143	152
45	18	45	78	104	127	142	153	162
50	23	55	88	114	135	150	161	170
55	28	62	96	122	142	157	168	177
60	34	69	103	128	148	163	174	182
65	39	75	108	134	153	168	178	187
70	44	80	115	138	158	172	182	191
75	49	85	117	142	161	176	186	194
80	53	88	120	145	164	179	188	196
85	56	92	123	148	166	182	191	198
90	59	94	124	150	168	184	192	199
95	61	96	126	151	169	185	193	200
100	62	97	127	152	170	186	194	200

DOMINANT TREES

Basal area in square feet								
15	24	33	41	48	54	57	62	64
20	33	45	57	66	75	81	84	88
25	38	51	64	76	84	91	95	101
30	41	56	70	84	93	100	106	112
35	45	60	76	91	101	109	116	122
40	48	64	81	97	108	117	124	130
45	50	68	86	102	114	123	131	137
50	53	71	90	107	119	129	137	144
55	55	73	94	111	124	134	143	150
60	56	76	97	114	128	139	148	155
65	58	78	99	117	131	142	152	159
70	59	79	101	120	134	146	156	163
75	60	81	103	122	137	149	159	166
80	61	82	105	124	139	151	161	169
85	61	83	106	125	141	154	164	172
90	62	84	107	127	143	156	165	173
95	63	85	108	128	145	157	166	175
100	63	86	109	129	146	158	167	176

¹(561, Tables 69, 75, 84, and 93).

Appendix VII—Diameter and Height Tables for Second-growth Longleaf Pine in Fully Stocked Stands

Table VII-a.—Breast-height diameters of second-growth longleaf pine in fully stocked stands on various sites¹

TREES 2 INCHES OR MORE D.B.H.								
Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
Diameter in inches								
15	1.7	2.2	2.5	2.8	3.2	3.5	3.9	4.2
20	2.4	2.8	3.3	3.8	4.3	4.7	5.2	5.6
25	2.9	3.5	4.2	4.7	5.3	5.9	6.4	6.9
30	3.4	4.1	4.9	5.5	6.1	6.7	7.4	7.9
35	3.8	4.6	5.5	6.2	6.9	7.6	8.2	8.9
40	4.2	5.1	6.0	6.8	7.6	8.3	9.0	9.8
45	4.5	5.6	6.5	7.4	8.2	9.0	9.8	10.7
50	4.8	5.9	7.0	7.9	8.8	9.6	10.5	11.4
55	5.1	6.3	7.4	8.4	9.3	10.2	11.1	12.1
60	5.4	6.6	7.8	8.8	9.8	10.7	11.7	12.7
65	5.7	6.9	8.1	9.2	10.2	11.2	12.2	13.3
70	5.9	7.2	8.5	9.6	10.6	11.6	12.7	13.8
75	6.1	7.5	8.8	10.0	11.1	12.1	13.2	14.4
80	6.4	7.8	9.1	10.3	11.5	12.5	13.7	14.9
85	6.6	8.0	9.4	10.7	11.9	13.0	14.2	15.4
90	6.8	8.3	9.8	11.0	12.3	13.4	14.6	15.8
95	7.0	8.6	10.1	11.3	12.6	13.8	15.0	16.3
100	7.2	8.8	10.3	11.7	13.0	14.2	15.4	16.7
TREES 4 INCHES OR MORE D.B.H.								
15	4.1	4.3	4.4	4.6	5.1	5.3	5.6	5.7
20	4.4	4.7	5.0	5.2	5.5	5.7	6.0	6.3
25	4.6	5.0	5.4	5.7	6.1	6.4	6.8	7.2
30	4.9	5.3	5.8	6.2	6.7	7.1	7.6	8.1
35	5.1	5.6	6.2	6.7	7.3	7.8	8.4	9.0
40	5.3	5.9	6.6	7.2	7.8	8.4	9.1	9.8
45	5.5	6.2	7.0	7.6	8.4	9.0	9.8	10.6
50	5.7	6.5	7.3	8.1	8.9	9.6	10.5	11.4
55	5.9	6.8	7.7	8.5	9.4	10.2	11.1	12.1
60	6.1	7.1	8.0	8.9	9.9	10.7	11.7	12.8
65	6.3	7.3	8.4	9.3	10.3	11.2	12.2	13.3
70	6.5	7.6	8.7	9.7	10.8	11.7	12.7	13.9
75	6.7	7.8	9.0	10.1	11.2	12.2	13.2	14.4
80	6.9	8.0	9.3	10.4	11.6	12.6	13.7	14.8
85	7.1	8.3	9.6	10.7	11.9	13.0	14.1	15.3
90	7.2	8.5	9.8	11.0	12.3	13.4	14.6	15.7
95	7.4	8.7	10.1	11.3	12.6	13.8	15.0	16.2
100	7.5	8.9	10.3	11.6	12.8	14.1	15.4	16.6
TREES 7 INCHES OR MORE D.B.H.								
15	----	----	----	7.2	7.4	7.6	7.7	7.8
20	7.0	7.1	7.3	7.4	7.5	7.7	7.8	8.0
25	7.2	7.3	7.5	7.7	7.8	8.0	8.2	8.5
30	7.3	7.5	7.7	7.9	8.1	8.4	8.7	9.1
35	7.4	7.6	7.9	8.2	8.5	8.9	9.3	9.8
40	7.5	7.8	8.1	8.5	8.9	9.4	9.9	10.5
45	7.6	7.9	8.3	8.8	9.3	9.8	10.5	11.2
50	7.7	8.1	8.6	9.1	9.8	10.3	11.0	11.8
55	7.8	8.3	8.8	9.4	10.1	10.8	11.6	12.4
60	7.9	8.4	9.0	9.8	10.5	11.3	12.1	13.1
65	8.0	8.6	9.3	10.0	10.9	11.7	12.5	13.5
70	8.1	8.7	9.5	10.4	11.2	12.1	13.0	14.0
75	8.2	8.9	9.8	10.7	11.6	12.5	13.5	14.5
80	8.3	9.0	10.0	11.0	12.0	12.9	14.0	15.0
85	8.4	9.2	10.2	11.3	12.3	13.3	14.4	15.4
90	8.5	9.4	10.5	11.5	12.6	13.6	14.7	15.8
95	8.6	9.5	10.7	11.8	12.9	14.0	15.1	16.2
100	8.6	9.7	10.9	12.1	13.2	14.3	15.4	16.6

¹(561, Tables 66, 73, 80, 91). Table continued on p. 295.

DOMINANT TREES

Age (years)	Site index, feet—						
	40	50	60	70	80	90	100
	<i>Diameter in inches</i>						
15	2.5	3.0	3.5	3.8	4.3	4.6	5.1
20	3.3	3.9	4.5	5.1	5.6	6.1	6.5
25	3.9	4.7	5.4	6.0	6.6	7.1	7.6
30	4.5	5.4	6.2	6.8	7.5	8.0	8.6
35	5.0	5.9	6.8	7.6	8.3	8.9	9.5
40	5.4	6.4	7.4	8.2	9.0	9.6	10.4
45	5.8	6.9	7.9	8.8	9.6	10.3	11.1
50	6.2	7.3	8.4	9.3	10.2	11.0	11.8
55	6.5	7.7	8.8	9.8	10.7	11.5	12.4
60	6.8	8.0	9.2	10.2	11.2	12.0	12.9
65	7.1	8.4	9.6	10.6	11.6	12.5	13.4
70	7.3	8.7	9.9	11.0	12.0	12.9	13.9
75	7.5	8.9	10.2	11.3	12.4	13.3	14.3
80	7.8	9.2	10.6	11.7	12.7	13.7	14.7
85	8.0	9.5	10.9	12.0	13.0	14.1	15.1
90	8.2	9.7	11.2	12.3	13.4	14.4	15.4
95	8.3	9.9	11.5	12.6	13.7	14.7	15.8
100	8.5	10.2	11.8	12.8	14.0	15.0	16.0

Table VII-b.—*Total height of second-growth longleaf pine, in fully stocked stands, on various sites*¹
AVERAGE HEIGHT FOR ALL TREES 2 INCHES OR MORE D.B.H.

Age (years)	Site index, feet—						
	40	50	60	70	80	90	100
	<i>Total height in feet</i>						
15	14	17	22	26	30	34	38
20	18	23	29	34	40	45	51
25	22	28	34	41	48	54	61
30	25	32	40	47	55	62	70
35	28	36	45	53	62	70	78
40	31	40	49	58	67	76	86
45	33	43	52	62	72	82	92
50	35	45	55	66	76	87	97
55	36	47	58	69	80	90	101
60	38	49	60	72	83	94	106
65	39	50	62	74	86	97	109
70	40	52	64	76	88	100	112
75	41	53	66	78	90	103	115
80	42	54	67	80	92	105	118
85	43	56	69	81	94	107	120
90	44	57	70	83	96	109	123
95	45	58	71	84	98	111	125
100	45	59	72	86	99	113	127

AVERAGE HEIGHT FOR DOMINANT TREES ONLY

15	14	18	22	26	30	33	37	41
20	20	26	31	36	41	46	52	57
25	25	32	38	45	51	57	64	70
30	30	37	44	52	59	66	74	81
35	33	41	49	57	66	74	82	90
40	36	45	53	62	71	80	89	98
45	38	47	57	66	76	85	95	104
50	² 40	² 50	² 60	² 70	² 80	² 90	² 100	² 110
55	42	53	63	74	84	94	105	115
60	44	55	65	77	87	98	109	120
65	45	57	68	79	90	102	113	124
70	47	58	70	82	93	105	117	128
75	48	60	72	84	96	108	120	132
80	49	61	73	86	98	110	123	135
85	50	63	75	88	100	112	125	137
90	51	63	76	89	101	114	127	139
95	51	64	77	90	102	115	128	140
100	52	65	77	90	103	116	129	142

¹(561, Tables 67 and 65).

²Italicized values are site indices.

Appendix VIII

Volume Tables for Second-growth
Longleaf Pine

Before using any volume table, one should know if it gives reliable estimates for the trees on which it is based, and is suited to particular needs. The aggregate difference and the average deviation—based on a comparison of the actual and estimated volumes of the trees used in making the table—should be small. To show how well a volume table fits any stand, a field test is needed. If there is a small aggregate difference, and an average deviation that agrees closely with that for the table, confidence in the table is justified (55). The aggregate difference in percent should not exceed 2½ times the average individual deviation (in percent) divided by the square root of the number of trees, if the volume table is to be applied without correction (561).

The following tables show volumes in board feet, in cubic feet, and in cords. Table VIII-c, upper part, is shown as an alinement chart in Figure 69 (page 238).

Table VIII-a.—Board-foot volume in trees of different merchantable lengths¹
INTERNATIONAL ¼-INCH RULE²

Diameter breast high (inches)	Number of 16-foot logs—						Basis, trees
	1¼	2	3	4	5	6	
	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	
6	15	20	—	—	—	—	17
7	17	26	40	—	—	—	77
8	19	33	53	74	—	—	89
9	21	41	68	96	124	—	45
10	24	48	82	117	152	190	35
11	26	55	97	139	182	224	27
12	29	62	112	163	213	263	11
13	—	71	127	187	244	304	9
14	—	78	143	212	277	346	5
15	—	85	160	238	312	391	15
16	—	93	178	265	350	438	9
17	—	101	197	293	390	488	11
18	—	110	216	322	430	538	1
Basis, trees	63	134	86	60	8	—	351

DOYLE RULE³

8	12	17	23	29	—	—	4
9	13	23	35	47	—	—	32
10	15	29	47	65	—	—	33
11	16	35	59	83	—	—	27
12	17	41	71	102	—	—	11
13	19	47	84	122	—	—	9
14	20	54	98	143	187	—	5
15	22	60	112	164	217	—	15
16	23	67	127	188	250	—	9
17	—	74	144	214	284	—	11
18	—	83	160	240	323	—	1
Basis, trees	21	62	45	26	3	—	157

¹Blocks indicate extent of basic data. Stump height, 1 foot; top diameter inside bark, 5 inches for upper table and 7 inches for lower table. Scaled in 16-foot log lengths, with 0.3-foot trimming allowance and additional top sections to the top diameters mentioned above.

²Calculated from International ¼-inch Rule as given in 561, Table 14. Average deviation of individual tree volumes from tabular values, ±6.2 percent; aggregate difference, +0.43 percent.

³(561, Table 16). Average deviation of individual tree volumes from tabular values, ±7.8 percent; aggregate difference, +0.03 percent.

Table VIII-b.—Board-foot volume in trees of different total heights¹INTERNATIONAL ¼-INCH RULE²

Diameter breast high (inches)	Total height, feet—								Basis, trees
	40	50	60	70	80	90	100	110	
	<i>Board Feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	
6	5	11	14	19	---	---	---	---	17
7	7	14	22	29	35	---	---	---	77
8	9	20	31	42	52	---	---	---	89
9	12	27	43	58	73	86	---	---	45
10	15	36	57	77	97	115	131	---	35
11	---	---	74	100	124	147	167	---	27
12	---	---	90	121	152	180	205	---	11
13	---	---	109	146	181	214	245	---	9
14	---	---	124	166	206	244	281	313	5
15	---	---	138	184	229	272	312	348	15
16	---	---	153	205	254	302	348	389	9
17	---	---	169	226	281	332	381	426	11
18	---	---	187	248	306	360	414	462	1
Basis, trees	3	47	113	83	73	27	5	---	351

SCRIBNER DECIMAL C RULE³

Volume in board feet, in <i>tens</i>								
7	---	---	---	1	1	2	---	63
8	---	1	2	3	4	5	6	101
9	1	3	4	5	6	7	8	70
10	2	4	6	7	8	10	11	53
11	3	5	7	9	10	12	14	40
12	4	7	9	11	13	15	17	21
13	5	8	10	13	15	18	20	16
14	6	9	12	15	18	21	24	13
15	7	10	14	17	20	24	27	16
16	---	11	15	19	23	26	30	9
17	---	13	17	21	25	30	34	10
18	---	14	19	24	28	33	38	1
19	---	16	21	26	31	37	42	---
20	---	17	23	29	34	40	46	---
Basis, trees	9	50	139	101	82	26	6	413

¹Blocks indicate extent of basic data. Stump height, 1 foot; top diameter inside bark, 5 inches for upper table and 6 inches for lower table. Scaled in 16-foot log lengths, with 0.3-foot trimming allowance and additional top sections to the top diameters mentioned above.

²Calculated from International ½-inch Rule as given in 561, Table 13. Average deviation of individual tree volumes from tabular values, ± 13.4 percent; aggregate difference, $+0.91$ percent.

³(561, Table 15). Average deviation of individual tree volumes from tabular values, ± 10.1 percent; aggregate difference, -0.6 percent.

Table VIII-c.—Cubic-foot volume of peeled wood¹
TOTAL VOLUME²

Diameter breast high (inches)	Total height, feet—											Basis, trees
	10	20	30	40	50	60	70	80	90	100	110	
	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>
2	0.1	0.2	0.2	0.3	—	—	—	—	—	—	—	—
3	.2	.3	.5	.7	.9	—	—	—	—	—	—	—
4	—	.6	.8	1.2	1.6	2.0	—	—	—	—	—	14
5	—	.8	1.3	2.0	2.5	3.1	3.8	—	—	—	—	69
6	—	1.2	2.1	3.0	3.8	4.7	5.6	6.3	—	—	—	95
7	—	1.6	2.8	4.1	5.4	6.7	7.8	8.8	9.8	—	—	88
8	—	—	3.8	5.3	7.2	8.8	10.3	11.8	13.2	—	—	89
9	—	—	—	6.8	9.1	11.2	13.2	15.2	17.2	—	—	45
10	—	—	—	8.3	11.2	13.8	16.5	19.1	21.6	24.3	26.9	35
11	—	—	—	—	13	17	20	23	26	30	33	27
12	—	—	—	—	16	20	24	28	32	35	39	11
13	—	—	—	—	18	23	28	32	36	41	45	9
14	—	—	—	—	21	26	31	36	42	47	52	5
15	—	—	—	—	23	29	35	41	46	52	58	15
16	—	—	—	—	26	32	39	45	52	58	64	9
17	—	—	—	—	28	35	42	50	57	64	71	11
18	—	—	—	—	—	—	—	54	62	69	77	1
Basis, trees	—	—	10	78	118	127	84	73	27	6	—	523

MERCHANTABLE VOLUME³

4	—	0.4	0.6	1.0	1.4	1.8	—	—	—	—	—	14
5	—	.5	1.0	1.7	2.2	2.8	3.5	—	—	—	—	69
6	—	.8	1.6	2.6	3.4	4.3	5.2	5.8	—	—	—	95
7	—	1.1	2.3	3.5	4.8	6.2	7.3	8.4	9.3	—	—	88
8	—	—	3.0	4.6	6.5	8.2	9.7	11.2	12.7	—	—	89
9	—	—	—	5.7	8.4	10.4	12.4	14.5	16.5	—	—	45
10	—	—	—	7.2	10.3	13.0	15.6	18.2	20.8	23.5	26.0	35
11	—	—	—	—	12.4	15.8	19.0	22.3	25.2	28.8	31.8	27
12	—	—	—	—	14.5	18.7	22.6	26.5	30.0	34.1	37.8	11
13	—	—	—	—	16.8	21.5	26.2	30.7	35.0	39.6	44.0	9
14	—	—	—	—	19.2	24.4	28.8	34.8	40.0	45.4	50.2	5
15	—	—	—	—	21.7	27.4	33.3	39.0	45.0	50.8	56.5	15
16	—	—	—	—	24.2	30.2	37.0	43.3	50.0	56.3	62.6	9
17	—	—	—	—	26.8	33.2	40.7	47.6	55.0	61.8	69.0	11
18	—	—	—	—	29.3	36.1	44.3	52.0	60.0	67.5	75.5	1
Basis, trees	—	—	10	78	118	127	84	73	27	6	—	523

¹Blocks indicate extent of basic data. Average deviation of individual tree volumes from tabular values, ± 7.2 percent; aggregate difference, -0.31 percent.
²(561, Table 9). Volume includes peeled stump, stem, and top.
³(561, Table 10). Volume includes peeled stem above a 1-foot stump to a top diameter, inside bark, of 3 inches.

Table VIII-d.—*Volume of merchantable wood in cords*¹
VOLUME OF ROUGH WOOD²

Diameter breast high (inches)	Total height, feet—										Basis, trees
	20	30	40	50	60	70	80	90	100	110	
	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>
4	0.00721	0.0107	0.0165	0.0220	0.0279	---	---	---	---	---	14
5	.00814	.0165	.0258	.0338	.0413	0.0492	---	---	---	---	69
6	.0123	.0238	.0365	.0490	.0595	.0702	0.0841	0.0960	---	---	95
7	.0164	.0320	.0485	.0665	.0830	.0960	.110	.125	---	---	88
8	.0210	.0410	.0618	.0865	.107	.126	.140	.158	---	---	89
9	.0264	.0509	.0760	.108	.133	.158	.178	.200	---	---	45
10	---	---	.0915	.129	.163	.194	.223	.247	0.278	0.303	35
11	---	---	---	.155	.196	.233	.270	.303	.339	.371	27
12	---	---	---	.181	.229	.275	.318	.357	.400	.439	11
13	---	---	---	.208	.263	.317	.366	.414	.463	.509	9
14	---	---	---	.238	.297	.359	.416	.472	.526	.579	5
15	---	---	---	.266	.331	.401	.465	.532	.592	.650	15
16	---	---	---	.295	.365	.445	.515	.590	.657	.723	9
17	---	---	---	.326	.400	.487	.567	.651	.722	.797	11
18	---	---	---	.358	.435	.532	.617	.711	.789	.869	1
Basis, trees	---	10	78	118	127	84	73	27	6	---	523
VOLUME OF PEELED WOOD ³											
4	0.00476	0.00714	0.0118	0.0162	0.0212	---	---	---	---	---	14
5	.00568	.0118	.0194	.0255	.0317	0.0397	---	---	---	---	69
6	.00889	.0178	.0284	.0382	.0473	.0571	0.0640	---	---	---	95
7	.0122	.0245	.0380	.0525	.0667	.0788	.092	0.109	---	---	88
8	---	.0318	.0486	.0690	.0870	.105	.118	.138	---	---	89
9	---	---	.0602	.0870	.107	.130	.152	.173	---	---	45
10	---	---	.0734	.107	.134	.162	.189	.214	0.244	0.269	35
11	---	---	---	.127	.163	.196	.230	.262	.298	.328	27
12	---	---	---	.149	.192	.232	.272	.309	.351	.390	11
13	---	---	---	.172	.220	.268	.313	.358	.406	.452	9
14	---	---	---	.197	.250	.304	.357	.408	.463	.514	5
15	---	---	---	.221	.278	.340	.398	.458	.518	.576	15
16	---	---	---	.246	.308	.377	.442	.510	.574	.640	9
17	---	---	---	.272	.338	.413	.485	.560	.630	.704	11
18	---	---	---	.298	.367	.452	.529	.612	.688	.768	1
Basis, trees	---	10	78	118	127	84	73	27	6	---	523

¹Blocks indicate extent of basic data. Volume includes stem above a 1-foot stump to a top diameter, inside bark, of 3 inches. Average deviation of individual tree volumes from tabular values, ± 7.2 percent; aggregate difference, -0.31 percent.

²(561, Table 11). Rough wood, i.e., wood and bark.

³(561, Table 12). Peeled stem, i.e., wood only.

Appendix IX

Normal Growth and Yield Tables for Second-growth Longleaf Pine

Normal growth and yield tables for longleaf pine have the following advantages:

(1) Longleaf pine often grows in pure, even-aged forests, consisting of relatively few stands that require separate treatment. The data from these few component stands can be handled without corrections for mixtures of ages or species.

(2) Although determination of site and age is required for each stand, no intensive studies of rates of timber growth and mortality in particular stands are necessary. The alternative procedure—stand-table projection—necessitates fact-finding timber cruises.

(3) The normal-yield tables are useful for long-term predictions of the yields possible under intensive management. No better basis for such forecasts is yet available.

The disadvantages of normal growth and yield tables are:

(1) The collection of data needed for adapting normal-yield tables to particular stands may cost as much as or more than alternative ways of determining yields. If so, local empirical tables or increment borings and a stand-table-projection method of forecasting may be used. If normal tables are used, the degree of stocking must be considered. In actual stands a certain amount of abnormal density cannot offset the natural (but so far unmeasured) tendency of a longleaf pine forest to attain normal volume with advancing age.¹ Corrections may be needed for different degrees of utilization.

(2) Existing tables are based on unmanaged stands in which the form and increment of stems have not been modified by thinning, turpentining, and control of fires. The stands measured as a basis for the tables were frequently burned.

(3) In some places misleading or erroneous results from computations based on the tables are traceable to the shape of the site-index curves and to the effects of changes in frequency of burning on growth rates and bark thickness.

(4) The life history of a single continuously normal stand may not be reflected exactly in tables built up from data taken in many separate stands that may have been abnormal at earlier dates. Also, the tables do not show yields during the period of decadence or over-maturity.

(5) Normal tables are based on total age of stands, which cannot be precisely determined by boring in longleaf pine because the years spent in the grass stage are not recorded by annual rings. In making the yield tables, total age was assumed to equal age at breast height plus 7 years.

The following tables should not be used as a substitute for an actual cruise in estimating the yield of a given tract. If the cost of surveys detailed enough to supply data for correcting the tables is prohibitive, then the tables can serve only as a standard of comparison.

¹The approach toward normality in the board-foot volumes of an understocked stand is relatively rapid at first but diminishes later. Stand volumes approach normality at different rates depending on initial stocking, but progress may be slow. For example, in Douglas-fir a stand 30 percent understocked may require 40 to 45 years to reach normal.

This approach to normal is usually deliberately neglected for the sake of a conservative estimate in using the normal tables, but corrections for wide differences in stocking are essential. Timber volumes from cruises may give approximate percentage deductions useful in adapting normal tables to local use. Other criteria of error also deserve consideration. For short-term forecasts of board-foot volumes, the number of trees per acre above a specified minimum merchantable diameter limit may furnish a useful index of normality. Basal area per acre provides a better index of normality when the cubic-foot yields of young stands are to be forecast or when long-term predictions for any stand are desired. In general, the basal area of a stand affords the most reliable criterion of the degree of normality in its stocking.

The suitability of the southern pine growth and yield tables has been challenged by Sylvester and Chapman (545, 107) based on a study of loblolly pine. The tables based on small plots show much higher normal yields, especially for advanced age classes, than can ever be found over large areas.

A more serious deficiency in normal-yield tables may be found in the curves used to classify sites and the extent to which the heights of local dominant trees scatter about such curves. For example, the curve depicting the trend of average height of dominant trees plotted over age flattens out earlier for trees on poor, hardpan sites than for those on good sites, and rises more abruptly for those on old fields than for those in natural second-growth stands on average sites. As a rule, better than average timber sites were cleared for farming, but some temporary condition in the soil resulting from former cultivation, such as the eradication of roots of hardwood trees, evidently contributed to this abrupt rise in the height curve. Whatever the cause, its effect is an overestimate of the site index for young timber on old fields. For example, a site index computed as 98 feet for 20-year-old trees might be only 79 feet when 30-year-old trees are used. R. A. Chapman (114) has called attention to the fact that the existing normal-yield tables for longleaf pine were based partly on natural stands (70 percent) and partly on old-field stands (30 percent), although the old-field curves are significantly higher and of different shape. This difference causes inaccuracy in forecasts based on the present tables.

Another factor that appreciably affects rate of height growth should be mentioned as a source of error in using the normal-yield tables. Defoliation by fire is known to retard growth in height, diameter, and volume. Retardation in height may reach 25 percent in young trees, but diminishes as crowns are elevated, thus modifying the form and position of curves of height plotted over age. When pines are grown with less than the former amount of defoliation, their site quality as measured on the basis of young trees and predicted from existing site-index curves (Fig. 70) will be high. There is no satisfactory way to estimate the magnitude of error because exact information is lacking on the frequency, severity, and effect of fires in the stands on which the tables were based.

Another common error made by those who use volume and yield tables may arise from the failure to take account of the variation in bark thickness. The bark on trees of pulpwood size usually accounts for a sizable portion of the total volume of unpeeled wood, as follows:

Size of tree (inches d.b.h.)	Volume of unpeeled wood in bark (percent)
6	22
8	20
10	18
12	15
14	14
16	12

Working with 35-year-old second-growth longleaf at Lanes, S. C., MacKinney (373) correlated single bark thickness with diameter of trees.² Four annual fires after 10 years' protection were found to reduce double bark thickness approximately 0.1 inch, while a single accidental fire after 14 years' protection caused a reduction of about 0.2 inch in all diameter classes. In studies made in southern Mississippi, annual fires had similar effects on bark, but reduced its thickness only two-thirds as much (583).

The trees measured as a basis for present volume tables were burned at average intervals of perhaps three or four years. The estimated volume of peeled wood in unburned stands may be slightly in error because bark is somewhat thicker on unscorched than on scorched trees at the point of measurement.

Normal tables cannot solve many of the practical problems of estimating timber volume and growth. The figures are unattainably high for extensive individual stands, but may be used as a standard of comparison for actual stands.

²He found that single bark thickness equals 0.0537 d.i.b. in inches plus 0.2322. This formula had a standard error of estimate of ± 0.106 inch and a correlation coefficient of 0.768, indicating that 59 percent of the variation in bark thickness is associated with diameter. There was little variation in bark thickness on different sides of the trees.

Table IX-a.—*Growth and yield, per acre, in volume of peeled wood from longleaf pine 4 inches or more d.b.h., from fully stocked, second-growth stands on various sites*¹

AVERAGE ANNUAL GROWTH								
Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>
15	---	0.07	0.20	0.33	0.53	0.80	1.00	1.07
20	0.05	.15	.30	.50	.75	1.00	1.20	1.30
25	.08	.24	.40	.64	.88	1.08	1.28	1.44
30	.13	.27	.47	.70	.93	1.17	1.37	1.50
35	.14	.31	.51	.74	1.00	1.20	1.40	1.54
40	.15	.32	.52	.78	1.02	1.22	1.42	1.58
45	.16	.33	.56	.78	1.02	1.24	1.44	1.58
50	.16	.34	.56	.78	1.02	1.24	1.44	1.58
55	.16	.35	.55	.78	1.02	1.24	1.44	1.58
60	.17	.33	.55	.77	1.00	1.22	1.42	1.57
65	.17	.34	.54	.77	.98	1.20	1.40	1.54
70	.17	.33	.53	.74	.97	1.19	1.37	1.50
75	.16	.32	.52	.73	.95	1.16	1.33	1.47
80	.16	.31	.50	.72	.92	1.12	1.30	1.44
85	.16	.31	.49	.71	.91	1.09	1.27	1.40
90	.16	.30	.48	.68	.88	1.07	1.23	1.37
95	.16	.29	.47	.66	.85	1.04	1.21	1.34
100	.16	.29	.46	.65	.83	1.02	1.18	1.31
YIELD								
	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>
15	---	1	3	5	8	12	15	16
20	1	3	6	10	15	20	24	26
25	2	6	10	16	22	27	32	36
30	4	8	14	21	28	35	41	45
35	5	11	18	26	35	42	49	54
40	6	13	21	31	41	49	57	63
45	7	15	25	35	46	56	65	71
50	8	17	28	39	51	62	72	79
55	9	19	30	43	56	68	79	87
60	10	20	33	46	60	73	85	94
65	11	22	35	50	64	78	91	100
70	12	23	37	52	68	83	96	105
75	12	24	39	55	71	87	100	110
80	13	25	40	58	74	90	104	115
85	14	26	42	60	77	93	108	119
90	15	27	43	61	79	96	111	123
95	15	28	45	63	81	99	115	127
100	16	29	46	65	83	102	118	131
---	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic Feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>
15	10	80	220	440	740	1,020	1,300	1,480
20	120	400	700	1,100	1,550	1,950	2,300	2,550
25	270	620	1,100	1,600	2,200	2,750	3,200	3,500
30	400	860	1,450	2,100	2,800	3,450	4,050	4,400
35	530	1,100	1,800	2,600	3,400	4,200	4,900	5,350
40	650	1,300	2,150	3,050	4,000	4,900	5,650	6,200
45	780	1,500	2,450	3,500	4,550	5,600	6,400	7,050
50	900	1,700	2,750	3,900	5,050	6,200	7,150	7,850
55	1,000	1,850	3,000	4,300	5,550	6,800	7,850	8,600
60	1,100	2,050	3,300	4,650	5,950	7,350	8,500	9,300
65	1,200	2,200	3,500	5,000	6,350	7,800	9,000	9,900
70	1,250	2,300	3,700	5,250	6,700	8,250	9,500	10,450
75	1,350	2,450	3,950	5,500	7,050	8,650	10,000	10,950
80	1,400	2,550	4,100	5,750	7,350	9,000	10,350	11,400
85	1,450	2,650	4,250	5,950	7,600	9,350	10,750	11,800
90	1,500	2,750	4,350	6,150	7,850	9,650	11,100	12,200
95	1,550	2,850	4,500	6,300	8,100	9,900	11,450	12,550
100	1,600	2,900	4,600	6,450	8,300	10,200	11,750	12,900

¹(561, Tables 81, 82, and 77).

Table IX-b.—Growth and yield, per acre, in volume of unpeeled wood from longleaf pine 4 inches or more d.b.h., from fully stocked, second-growth stands on various sites¹

AVERAGE ANNUAL GROWTH

Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>
15	----	0.13	0.33	0.47	0.73	1.07	1.33	1.47
20	0.05	.20	.40	.70	1.00	1.30	1.50	1.70
25	.12	.32	.56	.84	1.12	1.40	1.60	1.76
30	.17	.37	.63	.93	1.20	1.43	1.63	1.80
35	.20	.40	.69	.94	1.23	1.46	1.66	1.83
40	.22	.42	.68	.98	1.22	1.48	1.65	1.82
45	.22	.42	.69	.96	1.22	1.47	1.64	1.82
50	.22	.42	.68	.96	1.22	1.44	1.64	1.80
55	.22	.42	.67	.95	1.18	1.42	1.62	1.78
60	.22	.42	.67	.92	1.17	1.40	1.60	1.77
65	.22	.42	.66	.91	1.14	1.37	1.57	1.74
70	.21	.40	.64	.89	1.11	1.34	1.54	1.70
75	.21	.40	.63	.87	1.09	1.32	1.51	1.67
80	.21	.39	.61	.84	1.06	1.29	1.48	1.62
85	.21	.38	.60	.82	1.04	1.25	1.44	1.58
90	.20	.37	.58	.80	1.01	1.22	1.40	1.53
95	.20	.36	.57	.78	.99	1.19	1.36	1.49
100	.20	.35	.55	.76	.97	1.17	1.33	1.45

YIELD

	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>	<i>Cords</i>
15	----	2	5	7	11	16	20	22
20	1	4	8	14	20	26	30	34
25	3	8	14	21	28	35	40	44
30	5	11	19	28	36	43	49	54
35	7	14	24	33	43	51	58	64
40	9	17	27	39	49	59	66	73
45	10	19	31	43	55	66	74	82
50	11	21	34	48	61	72	82	90
55	12	23	37	52	65	78	89	98
60	13	25	40	55	70	84	96	106
65	14	27	43	59	74	89	102	113
70	15	28	45	62	78	94	108	119
75	16	30	47	65	82	99	113	125
80	17	31	49	67	85	103	118	130
85	18	32	51	70	88	106	122	134
90	18	33	52	72	91	110	126	138
95	19	34	54	74	94	113	129	142
100	20	35	55	76	97	117	133	145

	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>
15	20	160	420	800	1,210	1,540	1,870	2,160
20	150	500	1,000	1,500	2,050	2,550	2,950	3,250
25	350	850	1,500	2,100	2,800	3,440	3,950	4,300
30	550	1,150	1,900	2,700	3,500	4,250	4,900	5,350
35	750	1,450	2,350	3,300	4,200	5,050	5,800	6,300
40	900	1,700	2,750	3,800	4,900	5,800	6,600	7,200
45	1,050	1,950	3,100	4,300	5,500	6,500	7,400	8,100
50	1,200	2,150	3,450	4,750	6,000	7,150	8,200	8,950
55	1,300	2,350	3,750	5,200	6,500	7,800	8,850	9,700
60	1,400	2,550	4,000	5,600	7,000	8,350	9,500	10,500
65	1,500	2,700	4,300	5,900	7,450	8,900	10,100	11,100
70	1,600	2,850	4,500	6,200	7,850	9,400	10,700	11,700
75	1,700	3,000	4,700	6,500	8,200	9,900	11,200	12,200
80	1,750	3,150	4,900	6,800	8,550	10,250	11,600	12,700
85	1,850	3,250	5,100	7,000	8,900	10,650	12,100	13,200
90	1,900	3,350	5,200	7,200	9,150	11,000	12,500	13,600
95	1,950	3,500	5,350	7,400	9,400	11,300	12,800	14,000
100	2,000	3,600	5,500	7,600	9,600	11,550	13,100	14,300

¹ (561, Tables 79, 78, and 76).

Table IX-c.—Growth and yield, per acre, of saw timber from trees 9 or more inches d.b.h., and from dominant trees in fully stocked, second-growth longleaf pine stands on various sites¹

AVERAGE ANNUAL GROWTH OF TREES 9 INCHES OR MORE D.B.H. (Doyle Rule) ¹								
Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet
25	---	---	---	---	---	20	40	80
30	---	---	---	---	33	67	117	167
35	---	---	---	29	57	114	171	229
40	---	---	12	50	100	162	225	300
45	---	---	22	67	122	200	278	356
50	---	10	40	90	150	230	320	410
55	---	9	55	109	173	264	355	445
60	---	17	58	117	192	283	383	483
65	---	23	69	131	208	300	400	492
70	7	29	71	136	221	321	421	521
75	7	27	80	147	233	333	440	533
80	6	31	88	156	244	344	450	544
85	6	35	88	159	253	353	459	547
90	11	39	94	167	261	361	461	544
95	11	42	95	174	263	363	463	537
100	15	45	100	175	265	365	460	530
YIELD FROM TREES 9 INCHES OR MORE D.B.H. (Doyle Rule) ¹								
	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet
25	---	---	---	---	---	500	1,000	2,000
30	---	---	---	---	1,000	2,000	3,500	5,000
35	---	---	---	1,000	2,000	4,000	6,000	8,000
40	---	---	500	2,000	4,000	6,500	9,000	12,000
45	---	---	1,000	3,000	5,500	9,000	12,500	16,000
50	---	500	2,000	4,500	7,500	11,500	16,000	20,500
55	---	500	3,000	6,000	9,500	14,500	19,500	24,500
60	---	1,000	3,500	7,000	11,500	17,000	23,000	29,000
65	---	1,500	4,500	8,500	13,500	19,500	26,000	32,000
70	500	2,000	5,000	9,500	15,500	22,500	29,500	36,500
75	500	2,000	6,000	11,000	17,500	25,000	33,000	40,000
80	500	2,500	7,000	12,500	19,500	27,500	36,000	43,500
85	500	3,000	7,500	13,500	21,500	30,000	39,000	46,500
90	1,000	3,500	8,500	15,000	23,500	32,500	41,500	49,000
95	1,000	4,000	9,000	16,500	25,000	34,500	44,000	51,000
100	1,500	4,500	10,000	17,500	26,500	36,500	46,000	53,000
YIELD FROM DOMINANT TREES (International 1/4-inch Rule) ²								
	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet	Board feet
15	---	---	---	200	400	600	1,100	1,500
20	---	---	500	900	1,800	3,200	4,500	5,900
25	---	---	1,400	2,700	4,500	6,800	9,000	10,900
30	---	900	2,700	5,000	7,700	10,900	13,600	16,300
35	500	1,400	4,100	7,200	10,900	14,500	18,100	21,300
40	500	2,300	5,400	9,500	14,000	18,600	23,100	26,700
45	900	3,200	7,200	11,800	17,200	22,600	28,500	31,700
50	1,400	4,100	9,000	14,500	20,400	26,200	32,100	36,700
55	1,800	5,000	10,400	16,300	23,100	29,900	36,200	41,200
60	2,300	6,300	11,800	18,600	25,300	33,000	39,800	45,200
65	2,700	6,800	13,100	20,400	28,100	35,700	43,400	48,900
70	3,200	7,700	14,500	22,200	30,300	38,900	46,200	52,000
75	3,600	8,600	15,800	24,000	32,100	41,200	49,300	55,200
80	4,100	9,500	16,700	25,300	34,400	43,900	51,600	57,900
85	4,100	10,000	17,600	26,700	36,200	46,200	54,300	60,600
90	4,500	10,400	18,600	28,100	37,600	48,000	56,600	62,900
95	5,000	10,900	19,500	29,000	38,900	49,800	58,400	65,200
100	5,400	11,300	20,800	29,900	40,300	51,100	60,200	67,400

¹(561, Tables 90 and 89).

²Calculated from International 1/4-inch Rule as given in 561, Table 95.

Table IX-d.—*Growth and yield, per acre, of saw timber from trees 7 or 8 inches or more d.b.h., in fully stocked, second-growth stands of longleaf pine on various sites*¹AVERAGE ANNUAL GROWTH OF TREES 7 INCHES OR MORE D.B.H.
(International ¼-inch Rule)¹

Age (years)	Site index, feet---							
	40	50	60	70	80	90	100	110
	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>	<i>Board feet</i>
15	---	---	---	12	24	43	72	102
20	---	---	23	45	90	136	226	294
25	---	18	54	109	181	272	362	452
30	---	30	75	151	256	377	498	588
35	13	39	117	207	323	452	582	685
40	23	56	136	249	385	520	656	792
45	20	71	161	281	423	563	724	844
50	27	90	190	317	462	606	769	887
55	33	99	205	338	485	634	790	905
60	38	106	219	355	505	656	792	912
65	42	111	223	362	509	662	801	905
70	45	117	233	375	517	660	788	892
75	48	120	235	374	519	658	785	875
80	51	125	237	379	515	656	775	860
85	53	128	245	373	511	650	761	852
90	51	130	242	372	503	639	749	834
95	52	129	243	367	495	629	738	819
100	54	131	244	362	489	615	724	805

AVERAGE ANNUAL GROWTH OF TREES 8 INCHES OR MORE D.B.H.
(Scribner Decimal C Rule)²

	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens
15	---	---	---	---	---	1	2	3
20	---	---	---	1	3	5	8	13
25	---	---	2	3	7	12	20	28
30	---	1	3	7	13	22	34	43
35	---	1	5	11	20	32	44	54
40	---	2	7	15	27	40	50	61
45	1	3	9	20	32	45	56	66
50	1	4	12	23	35	48	59	68
55	1	5	14	25	38	51	62	70
60	2	6	16	27	39	52	62	70
65	2	7	17	29	40	52	62	70
70	2	8	18	29	40	52	61	69
75	3	8	18	29	40	51	61	69
80	3	9	19	30	40	51	60	68
85	3	10	19	29	40	50	59	66
90	3	10	19	29	39	49	58	65
95	3	10	19	29	38	48	57	63
100	4	10	19	28	38	48	56	62

YIELD OF TREES 8 INCHES OR MORE D.B.H. (Scribner Decimal C Rule)²

	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens	Board feet in tens
15	---	---	---	---	3	12	30	50
20	---	---	5	20	55	100	170	255
25	---	5	40	85	175	290	510	700
30	5	20	90	200	380	650	1,015	1,300
35	10	50	165	390	715	1,120	1,530	1,885
40	20	90	280	610	1,080	1,580	2,020	2,440
45	30	150	420	880	1,430	2,010	2,505	2,960
50	50	210	590	1,140	1,760	2,410	2,955	3,420
55	70	285	765	1,400	2,075	2,780	3,385	3,830
60	95	370	930	1,640	2,350	3,100	3,740	4,210
65	125	455	1,090	1,855	2,600	3,375	4,030	4,550
70	155	540	1,235	2,040	2,830	3,620	4,300	4,860
75	190	635	1,375	2,210	3,030	3,840	4,560	5,150
80	220	725	1,500	2,370	3,210	4,060	4,810	5,400
85	255	810	1,615	2,505	3,370	4,250	5,025	5,620
90	295	885	1,720	2,625	3,515	4,440	5,240	5,830
95	330	960	1,815	2,735	3,655	4,600	5,430	6,030
100	370	1,025	1,900	2,830	3,780	4,750	5,590	6,220

¹Calculated from International ¼-inch Rule as shown in 561, Table 86.²(561, Tables 88 and 87).

Table IX-e.—Growth and yield, per acre, in volume of wood from fully stocked, second-growth stands of longleaf pine on various sites¹

AVERAGE ANNUAL GROWTH IN TOTAL VOLUME OF PEELED WOOD FROM TREES 2 INCHES OR MORE D.B.H.

Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>
15	13	25	40	55	72	88	102	112
20	15	30	48	66	85	105	120	132
25	18	32	56	72	92	112	130	142
30	18	33	53	73	95	117	135	147
35	19	34	54	77	99	121	140	153
40	19	35	55	78	100	122	140	155
45	19	36	56	79	101	124	142	157
50	19	35	56	79	101	124	143	157
55	19	35	55	78	101	124	143	156
60	19	35	56	78	99	122	142	155
65	19	34	55	77	98	120	138	152
70	19	33	53	75	96	118	136	149
75	18	33	53	73	94	115	133	146
80	18	32	51	72	92	112	129	142
85	17	31	50	70	89	110	126	139
90	17	31	48	68	87	107	123	136
95	16	30	47	66	85	104	121	132
100	16	29	46	64	83	102	118	129

YIELD OF DOMINANT STAND IN TOTAL VOLUME OF PEELED WOOD								
15	150	300	450	650	850	1,050	1,200	1,300
20	250	450	750	1,000	1,350	1,650	1,900	2,100
25	300	650	1,000	1,400	1,750	2,200	2,600	2,800
30	400	800	1,250	1,750	2,250	2,750	3,250	3,500
35	500	950	1,500	2,100	2,700	3,300	3,900	4,300
40	600	1,100	1,750	2,450	3,200	3,900	4,500	5,000
45	700	1,250	2,000	2,800	3,600	4,450	5,200	5,800
50	750	1,400	2,200	3,100	4,050	5,000	5,800	6,450
55	800	1,500	2,450	3,450	4,500	5,500	6,400	7,100
60	900	1,650	2,650	3,750	4,850	5,950	6,950	7,700
65	1,000	1,750	2,850	4,000	5,200	6,400	7,400	8,250
70	1,000	1,850	3,000	4,250	5,500	6,800	7,900	8,750
75	1,100	1,950	3,200	4,500	5,800	7,150	8,250	9,200
80	1,100	2,000	3,300	4,650	6,050	7,450	8,600	9,550
85	1,150	2,100	3,400	4,850	6,250	7,700	9,000	9,950
90	1,200	2,200	3,500	5,000	6,450	8,000	9,300	10,300
95	1,200	2,250	3,600	5,150	6,650	8,200	9,600	10,600
100	1,250	2,300	3,700	5,300	6,850	8,450	9,900	10,950

YIELD OF TREES 2 INCHES OR MORE D.B.H. IN TOTAL VOLUME OF PEELED WOOD								
15	200	375	600	825	1,075	1,325	1,525	1,675
20	300	600	950	1,325	1,700	2,100	2,400	2,650
25	450	800	1,400	1,800	2,300	2,800	3,250	3,550
30	550	1,000	1,600	2,200	2,850	3,500	4,050	4,400
35	650	1,200	1,900	2,700	3,450	4,250	4,900	5,350
40	750	1,400	2,200	3,100	4,000	4,900	5,600	6,200
45	850	1,600	2,500	3,550	4,550	5,600	6,400	7,050
50	950	1,750	2,800	3,950	5,050	6,200	7,150	7,850
55	1,050	1,900	3,050	4,300	5,550	6,800	7,850	8,600
60	1,150	2,100	3,350	4,650	5,950	7,350	8,500	9,300
65	1,250	2,200	3,550	5,000	6,350	7,800	9,000	9,900
70	1,300	2,300	3,700	5,250	6,700	8,250	9,500	10,450
75	1,350	2,450	3,950	5,500	7,050	8,650	10,000	10,950
80	1,400	2,550	4,100	5,750	7,350	9,000	10,350	11,400
85	1,450	2,650	4,250	5,950	7,600	9,350	10,750	11,800
90	1,500	2,750	4,350	6,150	7,850	9,650	11,100	12,200
95	1,550	2,850	4,500	6,300	8,100	9,900	11,450	12,550
100	1,600	2,900	4,600	6,450	8,300	10,200	11,750	12,900

See note at end of table, p. 307.

Table IX-e.—*Growth and yield, per acre, in volume of wood from fully stocked, second-growth stands of longleaf pine on various sites¹—Continued*

YIELD OF TREES 2 INCHES OR MORE D.B.H. IN TOTAL VOLUME OF UNPEELED WOOD

Age (years)	Site index, feet—							
	40	50	60	70	80	90	100	110
	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>	<i>Cubic feet</i>
15	350	750	1,150	1,500	1,750	2,000	2,200	2,450
20	500	1,000	1,500	2,000	2,450	2,800	3,150	3,450
25	650	1,200	1,900	2,500	3,100	3,600	4,050	4,400
30	800	1,450	2,200	3,000	3,700	4,350	4,950	5,350
35	950	1,650	2,550	3,500	4,300	5,100	5,800	6,300
40	1,100	1,850	2,900	3,950	4,900	5,800	6,600	7,200
45	1,250	2,050	3,200	4,400	5,500	6,500	7,400	8,100
50	1,350	2,250	3,550	4,800	6,000	7,150	8,200	8,950
55	1,450	2,400	3,800	5,200	6,500	7,800	8,850	9,700
60	1,550	2,600	4,100	5,600	7,000	8,350	9,500	10,500
65	1,650	2,750	4,350	5,900	7,450	8,900	10,100	11,100
70	1,700	2,950	4,600	6,200	7,850	9,400	10,700	11,700
75	1,800	3,100	4,800	6,500	8,200	9,900	11,200	12,200
80	1,850	3,200	4,950	6,800	8,550	10,250	11,600	12,700
85	1,900	3,350	5,150	7,000	8,900	10,650	12,100	13,200
90	1,950	3,450	5,300	7,200	9,150	11,000	12,500	13,600
95	2,000	3,500	5,450	7,400	9,400	11,300	12,800	14,000
100	2,050	3,600	5,550	7,600	9,600	11,550	13,100	14,300

¹(561, Tables 72, 94, 71, and 70).

Appendix X

Special Uses of Longleaf Pine Land

In addition to producing wood and naval stores, longleaf pine land is often used for grazing livestock and as a habitat for upland game, particularly quail. Some forest land is being converted to agricultural use or to plantations of tung trees. A brief discussion of these diverse crops is therefore worth consideration.

CATTLE

The principal southern range for cattle is in the longleaf-slash pine forest type (586) (Pl. 48). It consists of relatively open, grassy areas scattered through the forest and embraces 40 to 50 million acres on the Coastal Plain from North Carolina to Texas. The mild winters, hot summers, usually abundant rainfall throughout the year, and long growing seasons are conducive to rapid growth of vegetation.

At present, nearly all the cattle owned by farmers are handled in small herds for the most part and allowed to range at large, although fenced management is slowly increasing. The cattle industry contributes an important part of the income and subsistence of southern farmers. The number of packing plants, creameries, and cheese factories in the South is gradually increasing and the region may someday become self-sufficient in livestock and livestock products.

Only a small percentage of the blooded cattle of the country are in the South, but the process of gradually breeding up stocks, using local cows as the foundation of the herd, is well under way. The piney-woods cattle are readily improved through breeding. They transmit their own hardiness and the first generation acquires some of the superior meat-producing quality of the blooded sires (169). The forage resources of southern forest ranges, however, are best adapted to the production of "feeder" and "stocker" cattle and grass-fat animals. These offer little competition to the highly finished meat products of midwestern feed lots.

The native herbage of the longleaf pine range consists largely of such grasses as the beard-grasses or "broomsedges" and the three-awns or "wiregrasses," augmented by a scattering of switch canes and other broad-bladed grasses and swamp plants. The palatability of the native pineland grasses is, in general, rather low, although during the spring excellent grazing is available on burned-over areas for a period of about 90 days. Warm, moist weather brings about a rank growth and early maturity. The protein content and hence the nutritive value drops rapidly as maturity approaches. If the animals have access to forage plants in adjacent hardwood types of forest, their grazing season is extended. Bottom-land plants supply important winter feed, but excessive grazing or unregulated burning can reduce the supply.

The usual grazing capacity of unimproved pineland range (including hardwood bays) is 10 acres per head. On areas used during spring and early summer, about 5 acres of forage at full density are needed by each mature animal; on areas grazed in spring, summer, and early fall, about 8 acres; and at least 15 acres on year-long range in the Lower Coastal Plain (38). Supplemental feeding of cottonseed meal improves the appetite of cows for native forage. Year-long grazing without supplements is unsatisfactory (39).

About 70 percent of the year-long sustenance of southern herds of beef cattle is obtained from forest range. Fenced control of this range, frequently through nominal leasing arrangements between timber companies and local residents, is increasing. Better distribution of stock can be obtained through adjustments in water supplies and the placement of mineral or feed supplements as well as the rotation of range-burning treatments.

It is recognized that burning is essential to the grazing of longleaf pine lands. It has also been demonstrated that range burning can be well rotated and controlled with little result-

ing defoliation of trees. Range interests require the burning-over of a minimum area each winter to freshen the grass, but a different area can be treated each year in the burning cycle. Because intervals of 2 to 10 years are suitable for many purposes (silvicultural, sanitary, or protective), it is often possible to accomplish several objectives with a single fire or burning schedule. Properly planned, multiple-purpose burning is an economical measure in handling longleaf pine lands.

Burning hastens spring growth of forage plants, thus making forage available earlier, but it does little to extend the late-season capacity of range land to support cattle. Burning removes undesirable accumulations of dead grass and checks the invasion of worthless brush.

The nonindigenous carpet grass (*Axonopus compressus*), notable for its prostrate growth habit and high palatability, has become established in many spots widely scattered over the longleaf pine range lands. Under close grazing it gradually extends itself in competition with native grasses, whether burned over or not. It spreads with runners and reseeds naturally on mineral soil exposed by erosion, or along ditches and old woods roads or fire lanes. The seeds pass uninjured through the digestive tracts of cattle and are thus carried to new locations, where they start new spots of growth, which, if close grazing continues, can push the native grasses farther back. Carpet grass withstands closer cropping and heavier trampling than any native range grass. Cattle crop it so closely that it does not carry fire. Open places may be burned and sown after the last frost, allowing livestock to tramp the seeds into the soil. Seeding costs in 1942 were from \$2 to \$6 per acre or 0.7 mile of 12-foot roadbed (86). In old fields and along forest roads and trails, carpet grass not only provides excellent additional feed for range cattle, but also checks erosion (native grasses are non-sod-forming) and facilitates control of fires. Carpet grass will produce 3 to 20 times more beef per acre than will unimproved, native grass range.

In addition to carpet grass, a number of other species of grasses and legumes which have been introduced and become naturalized in the South have proved to be of high forage value. The most notable are Bermuda grass (*Cynodon dactylon*) and Johnson grass (*Sorghum halepense*). Bermuda grass is found mainly along roadsides and ditches and in abandoned fields, usually on good soils. Johnson grass is a notorious invader of cotton fields. The carrying capacity of these grasses is much greater than that of native species, but their occurrence on the forest range is still limited to roads, fire lines, trails, and closely grazed spots.

Improved pastures cover only a small area in the South, but are gradually increasing and are of great potential importance. If intensively grazed carpet-grass pastures are allowed to rest, the nutritive value is retained into late summer and fall; if desired for winter grazing, the livestock must be removed in July or August. The most promising forage plants for summer pasturage are common annual lespedeza (*Lepedeza striata*), certain clovers (*Trifolium* spp.), kudzu (*Pueraria thumbergiana*), Bermuda grass, and Dallis grass (*Paspalum dilatatum*). These plants are extremely hardy, withstand heat and drought, and renew themselves vegetatively with a high degree of success. They respond to fertilizer, are nutritious after the native grasses decrease in forage value in midsummer, and may supplement or replace carpet grass in the process of improving pastures.

Gleanings from field crops or supplemental feed, or both, are needed in the South to bring cattle through the winter in good condition. Feeds for winter use can be put up at very reasonable cost. The production of hay is more difficult in this prevailingly moist climate than in drier regions, although yields per acre are satisfactory. Cow-peas, lespedeza, and grasses constitute the principal hays. With the invention of the trench silo, the use of sugar cane and sorghum as silage has become more general. Dairy cattle are also fed cottonseed meal, corn, and home-grown or imported grain feeds.

At least 90 percent of the forest land in the South is privately owned, and much of it is in the hands of owners with extensive holdings who have not shown much interest in livestock production. In accordance with age-old custom, southern landowners usually tolerate grazing on their forest lands by the livestock of numerous small farmers. The typical forest range is open, no permits are required, no fees are charged, and usually no attempt is made to control fires set by stock owners.

The ability of cattle to survive despite lack of care has allowed the stigma of cheapness to become attached to the southern livestock industry. Many farmers spend nothing on the care of their livestock and expect them to yield little. Laws designed to force owners to keep animals under fence have been adopted in certain localities, but have not been generally enforced where agricultural crops are of minor value, as is the case in most areas in the longleaf pine belt. It has been regarded as more economical in such cases to fence in the cropland instead of the range, thus foregoing the advantages from better control of grazing.

Where forestry and grazing enterprises are attempted on the same land in the longleaf pine belt, perfect harmony can never be achieved. The interests of one cannot be vigorously promoted without injury to the other. On the other hand, cattle do reduce fire hazards to some extent and they help to pay carrying charges on a forestry investment in cut-over lands, especially in the early stages of development of forest stands. In colonial times most of the forest landowners were glad to have their longleaf pine lands burned over and grazed, but only because at that time no hopes were cherished for a second crop of timber. The unavoidable conflict between grazing and forestry becomes increasingly plain as land use is intensified with the growth of population, particularly near industrial centers. Ultimately, the problem can be satisfactorily solved in many places only by placing these two uses on separate tracts. In several places this point has already been reached, but many owners in the pure longleaf type, already past the period of unconcern whether more trees are grown or not, are not yet ready to begin intensive separate-use development of their lands. Nonintensive, dual use is both prevalent and profitable. No one who has woodland range suitable for cattle can afford to neglect the opportunity for additional income from livestock. The highest rewards go to owners who can integrate the dual uses skillfully and conservatively (587).

QUAIL

Approximately a million acres of longleaf and slash pine lands in South Carolina, Georgia, and Florida are owned and used primarily for hunting quail and other upland game. On many of these areas, and also on lands used primarily for timber or naval stores production, hunting rights are leased. Stoddard (533), the outstanding authority on upland-game management in the South, has shown that dual use of the land for wildlife and forestry should be carefully fitted into the natural land pattern of open, brushy, and wooded areas.

An essential feature of quail management is the use of carefully controlled fire for the purpose of regulating cover and increasing the food supply. Stoddard (537) says that: "Experience during the past 15 years over quail lands of the Southeast has fully shown that more quail lands are being damaged, so far as quail production is concerned, by mistaken attempts at fire exclusion than by any other single factor." "We believe that burning at the right time, in the right amount, with the proper frequency, and in a way to accomplish the desired results with the least damage to other interests, is the most important single operation involved in quail management in the region."

A fire in May or June, when eggs are hatching, may destroy many fledglings and greatly reduce the food supply. On the other hand, a mat of tangled grasses and pine needles prevents quail from getting at seed that may be present on land unburned for several years. Attempts to exclude fire have sometimes resulted in increased damage from an unwanted fire.

The season of burning also affects many plants whose seeds quail eat. "If burned over in February," says Stoddard (533), "after the seeds have matured and fallen and before new growth has started, by fires of the 'creeping' type, the ground is cleared of accumulated grasses, and the legumes, especially the perennials, appear stimulated, grow thriftily, and seed well and abundantly." Following a winter fire, these legumes are more thrifty and abundant on the burned-over than on the unburned areas; after a spring or summer fire, the reverse is true. Range bearing an abundance of valuable Japan clover or common lespedeza should never be burned after germination has begun, because eradication is likely to result. The partridge pea (*Chamaecrista* sp.), also palatable to quail, calls for different treatment. Lands

known to be seeded to this plant should be burned over after the danger from late frosts is past and before growth has started (533).

A supply of various small fruits, well distributed over quail nesting grounds, is most likely to be found where the land has been burned over once in several years rather than annually. Stoddard says: "The occurrence of sweeping annual fires means that little or no fruit will be produced on sections affected, since many of the small fruit-producing plants and shrubs fail to bear during the first season after a fire; on the other hand, an occasional fire seems to serve as a pruning and stimulates fruiting for several succeeding seasons. The first year, however, is required to renew the above-ground growth, a fact long known by the majority of rural people to be true in the case of huckleberries and blueberries, but this applies equally also to many other fruiting shrubs." A close network of irregular fire lines also increases food and nesting opportunities for quail.

Studies in southern Georgia (533) have shown that tree mast is a very important element in the diet of quail. While most tree seeds are available from November to March, longleaf pine seeds, because of prompt germination, can be found only for about six weeks in the fall. Acorns and sweetgum seeds are often available to quail in the longleaf pine region.

According to Stoddard (533), there are six reasons why areas abounding in leguminous plants are attractive to quail: "First, leguminous plants support a more abundant insect life than do most other classes of plants; second, they thrive only in well-drained soil (also a requirement of young quail); third, they produce foliage in such abundance that grasses and other low-growing plants are smothered out, leaving the ground underneath open and easy of passage for quail; fourth, the canopy of foliage formed by leguminous plants is sufficient to cause the birds to feel secure against the attack of hawks; fifth, leguminous plants produce a bounteous food supply of a kind much sought after by quail; and sixth, they enrich the soil to the point that other favorite food plants, such as ragweeds, can flourish and produce a more abundant and varied diet."

Turpentine operations and domestic grazing animals are not desirable on game preserves, but the production of large saw timber, harvested at relatively long intervals, should not impede game production (535). Even with intensive management of longleaf pine land for tree products, however, it is possible to increase quail production by using fire to promote the growth of legumes and other favorite food supplies.

TUNG OIL

Among the most interesting recent developments in the longleaf pine belt within about 100 miles of the Gulf of Mexico is the culture of tung trees (*Aleurites fordii*). The seeds of this tree, a native of China, yield a yellow oil that is used in the manufacture of high-grade paints and varnishes and in many other products. Tung oil is notable for its quick-drying and waterproofing qualities. In 1939, United States consumption was about 100 million pounds, less than 5 percent of which was produced in this country. At that time there were about 175,000 acres of tung trees in the United States, distributed as follows: Mississippi, 75 percent; Louisiana, 14 percent; Florida, 9 percent; Alabama, Georgia, Texas, and South Carolina, 2 percent. Most of these trees are on former longleaf pine land, although not all longleaf pine soils are suitable. Tung trees thrive on well-drained, permeable, acid soils with a deep water table. There is a promising future for tung-oil production in suitable localities, under intensive management based on the best available knowledge.

Appendix XI

Glossary¹

A

- Actinomyces.** A genus of filamentous bacteria of the family *Actinomycetaceae*, including numerous soil-inhabiting saprophytes and disease-producing plant and animal parasites.
- Ament.** A catkin; a unisexual spike of staminate flowers with scaly bracts, usually deciduous in one piece.
- Anther.** The part of the stamen which develops and contains pollen; a collective name for the microsporangia.
- Apophysis.** An enlargement or swelling of an organ, as in the scales of a pine cone.
- Apron.** A flat metal strip attached or inserted in a horizontal plane in a tree immediately above the cup to direct the oleoresin from the face into the cup.
- Area, basal.** The area, usually expressed in square feet, of the cross section at breast height of a single tree or of all the trees in a stand.
- Ascospore.** One of the spores contained in an ascus, which is the membranous ovoid or tubular spore sac in fungi of the class *Ascomycetes*. Ascosporous, adj.; ascosporic, adj.
- Axil.** The upper angle formed by the attachment of a leaf, flower, or other organ to a stem.

B

- B and Better.** Grade of lumber, denoting stock of good appearance and suitable for natural finishes. It consists of the two upper classes of the "select" grades: A, practically free from defects, and B, allowing a few small defects or blemishes.
- Backfire.** A fire intentionally set along the inner edge of a control line located ahead of an advancing fire, for the purpose of facilitating control by a widening of the control line and the removal of intervening combustible materials.
- Bar, bark.** The vertical strip of bark left between turpentine faces on a tree. Syn. *Life bar*.
- Barrens, pine.** Level tracts of light sandy soils openly stocked with pines.
- Bifid.** Forked, opening with a median cleft; divided nearly to the middle line.
- Box.** A V-shaped notch or excavation chopped in the base of a tree to collect gum. Boxes have been superseded by metal or earthenware cups.
- Bract.** A leaflike structure, or reduced leaf, from the axil of which a flower or floral axis arises.
- Buck.** To saw felled trees into shorter cuts.
- Buds, adventitious.** Buds arising abnormally, without order, anywhere on a plant.
- Burning, controlled.** Deliberate use of fire on land, whereby burning is restricted to a pre-determined area and intensity.
- Burning, light.** Prescribed burning at intervals of time so spaced that only a relatively small amount of fuel accumulates between such repeated burning, in order that accidental fires will be of low intensity, cause little damage, and be easily controlled.
- Burning, prescribed.** The application of fire to land under such conditions of weather, soil moisture, time of day, and other factors as presumably will result in the intensity of heat and spread required to accomplish specific silvicultural, wildlife, grazing, or fire-hazard reduction purposes.

C

- Calyx.** The flower cup or outermost part of a perianth, below the corolla. The perianth is the envelope of a flower consisting of both calyx and corolla, or either alone.

¹Many of these definitions are taken from *Forestry Terminology*, published by the Society of American Foresters (1944).

- Cambium.** A sheath of generative tissue between xylem and phloem, giving rise to secondary xylem (wood) and phloem (inner bark), and thus increasing the diameter or thickness of a trunk and its branches.
- Capacity, germinative.** The percent of seeds actually germinating, regardless of time. Syn. *Germination percent*.
- Carpel.** A simple pistil or a unit of a compound pistil; the female organ of a flower, consisting of ovary and stigma, and frequently a style in between. *Carpellary*, adj.
- Catface.** 1. A defect on the surface of a log, generally elliptical in shape, resulting from wounds where healing has not reestablished the normal cross section; also a fire scar at the base of the tree. 2. In pathology, a well-defined healing or healed wound on the bole of a tree, usually at the base.
- Cellulose.** An inert and complex carbohydrate occurring in all vegetable material and constituting about 50 percent of the cell walls of wood. Alpha-cellulose, a form distinguished on the basis of its behavior toward certain reagents.
- Chain.** A 66-foot linear unit used in land surveying; a square chain equals 0.1 acre.
- Chip.** The narrow strip of sapwood removed from a tree in order to stimulate the flow of gum.
- Class, crown.** A designation of trees in a forest with crowns of similar development and occupying similar positions in the crown cover. The following four crown classes are commonly recognized: dominant, codominant, intermediate, and overtopped.
- Classification, fuel-type.** The division of forest areas into units according to both the normal rate of spread of fire on an average bad day and the resistance to control-line construction offered by the fuels, topography, and soil.
- Clear-cut.** Cut-over areas on which the young growth that has come in is insufficient for them to be classified as second growth or reproduction.
- Climax.** The culminating stage in plant succession for a given natural environment.
- Coefficient, hygroscopic.** The moisture, in percentage of dry weight, that a dry soil will absorb in saturated air at a given temperature.
- Coefficient, wilting.** The value approximating the permanent wilting point, obtained by dividing the moisture equivalent by 1.84.
- Collar, root.** The dividing zone between stem and root. Usually recognized in trees and seedlings by the presence of a slight swelling.
- Compartment.** An organization unit or small subdivision of forest area for purposes of orientation, administration, and silvicultural operations, and defined by permanent boundaries, either of natural features or artificially marked, which are not necessarily coincident with stand boundaries.
- Conidium.** A fungal spore asexually produced and usually borne on sterigmata. *Conidial*, adj.
- Conk.** A definite, individual fruit-body of a wood-destroying fungus, which projects to some degree above the level of the substratum, or a sterile projecting fungous growth which resembles a fruit-body. As originally used, the term referred only to fruit-bodies of such evident types as those of the genera *Fomes* and *Polyporus* on trees.
- Corolla.** The petals of a flower.
- Correlation, coefficient of, index of.** A measure of the degree of relationship or association between two or more variables, and expressed as +1 for complete positive association, -1 for complete negative association, and 0 for no association. *Coefficient* applies to straight-line relationships, *index* to curvilinear relationships.
- Cortex.** Commonly the bark or rind. Anatomically, that portion of the primary body which surrounds the central cylinder (stele); limited externally by the epidermis and within by the endodermis, as in roots, pine needles, and some herbaceous stems. *Cortical*, adj.; *subcortical*, below the cortex.
- Cotyledon.** The primary leaf or leaves in the embryo, sometimes eventually performing the function of foliage leaves, but more often furnishing nourishment to the growing embryo.
- Cover, ground.** All herbaceous plants and low-growing shrubs in a forest.

- Crook.** A defect in logs, poles, or piles consisting of an abrupt bend.
- Crop.** A unit of 10,000 faces used in working pine trees for naval stores.
- Cull.** 1. A tree or log of merchantable size rendered unmerchantable because of defects.
2. The deduction from gross volume made to adjust for defect.
- Culture, monosporous.** A nutrient medium inoculated with a single spore or the fungus developed therefrom.
- Cup.** In turpentine, a receptacle to catch the gum, usually galvanized sheet-iron, clay, or aluminum.
- Cuppage.** Trees bearing turpentine cups or available for the hanging of such cups.
- Cupping, close.** Nonconservative turpentine, especially over-working trees by cutting too many faces.
- Cuspidate.** Terminating in a sharp or rigid point.
- Cutting, preparatory.** A felling to fit the stand for its reproduction by the removal of dying and defective trees and undesirable species, and to encourage seed production. Preliminary to seed or reproduction cutting.
- Cutting, release.** A liberation or improvement cutting by which young growth is freed from oppression by undesirable trees.
- Cutting, seed.** Further opening of a stand, before seeding takes place, to obtain the amount of open space which the expected seedlings will require. Syn. *Reproduction cutting*.

D

- D.b.h.** Diameter breast high; the diameter of a tree at $4\frac{1}{2}$ feet above ground; measurements are assumed to have been taken outside the bark. The additional initials i.b. are used to indicate inside bark.
- Deal.** In the southern yellow pine export trade, a piece of lumber 9 inches or more in width and 3, 4, or 5 inches thick.
- Dehiscence.** The opening of an anther or capsule by slits or valves.
- Dichotomy.** A system of branching in which the axis forks repeatedly into two usually equal branches.
- Dip.** Oleoresin or gum gathered from cups rather than scraped from the faces of trees. To dip: to extract gum from the cups.
- Diphyllody.** State of having two leaves.
- Dorsal surface.** The outer surface of an organ, turned away from the axis; as the under or outer surface of a leaf.
- Duct, median.** A resin canal located in the midst of the mesophyll of a leaf; a resin passage intermediate between internal and external parts of the mesophyll.

E

- Ectotrophic.** Nourished from without.
- Edaphic.** Pertaining to, or influenced by, soil conditions, rather than climatic, biotic, or other factors.
- Edgings.** The waste strips cut from squared boards.
- Embryo.** The rudimentary plant within the seed; sometimes called the germ.
- Endoderm. Endodermis.** A single layer of living cells, the innermost layer of the cortex with characteristically thickened walls and no intercellular spaces, which surrounds the vascular tissues, especially in roots, pine needles, and some stems.
- Endosperm.** The nutritive tissue formed within the embryo sac of seeds.
- Endotrophic.** Nourished from within.
- Energy, germinative.** The percent of seed germinating at the time the trend of germination reaches its peak.
- Epidermis.** The thin layer of cells forming the external integument in seed plants and ferns.
- Epiphyte.** A plant which grows upon other plants but is not parasitic, derives the moisture required for its development chiefly from the air; an air plant.

F

- Face, dry.** A natural cessation or partial failure in the flow of gum from trees during the period of turpentineing. Syn. *Dead face*.
- Facer, tree.** Turpentineing tool. See *Hogal*.
- Fascicle.** A bundle or cluster of leaves borne with a sheath, like most pine needles. A close cluster of flowers, leaves, stems, or roots. Fascicular, adj.
- Fatwood.** See *Lightwood*.
- Fertilization.** The effect of deposition of pollen on a stigma of a flower, resulting in the conversion of flower into fruit and ovule into seed.
- Fibrovascular.** Having or consisting of fibers and conducting cells; as a fibrovascular bundle, composed principally of xylem and phloem.
- Firebreak.** An existing barrier, or one constructed before a fire occurs, from which all or most of the inflammable materials have been removed: designed to stop or check creeping or running but not spotting fires, or to serve as a line from which to facilitate the movement of men and equipment in fire suppression.
- Fire-climax.** A plant community in equilibrium with an environment including recurring fires, and self-perpetuating so long as the fires and other conditions persist essentially unchanged.
- Fire, creeping.** A fire spreading slowly, usually with low flame.
- Fire, crown.** A fire that burns through the tops of trees, or which consumes a large part of the upper branches or foliage.
- Fire, head of a.** The portion of the edge of a fire on which rate of spread is most rapid.
- Fire, spot.** A fire started as a result of sparks or embers falling in advance of, or away from, the main fire.
- Fire, surface.** A fire that runs or creeps over the forest floor burning only the surface litter, the loose debris, and the smaller vegetation or ground cover. Syn. *Ground fire*.
- Flap.** A piece of leather or composition belting 8 to 12 inches wide and a foot or more in length secured to a straight handle for use in beating out grass fires. Syn. *Fire swatter*.
- Flatwoods.** Flat pine land in the lower Gulf Coastal Plain.
- Floor, forest.** The deposit of dead vegetable matter on the ground in a forest. Includes litter and unincorporated humus. Syn. *Duff*.
- Foliage, primary.** A distinctive juvenile form of leaves, assumed to be similar to adult leaves of the ancestral plant in an early stage of its development.
- Forest, normal.** A standard with which to compare an actual forest to bring out its deficiencies for sustained-yield management; an ideally regulated or organized forest with normal increment, age classes normal in area and distribution, and normal growing stock.
- Formation, Catahoula.** An upper stage of the Oligocene epoch of the Tertiary period of the Cenozoic era; a geologic formation containing firm sandstone. Syn. *Typical Grand Gulf*.
- Formation, Fayette.** White sands and joint clays deposited by fresh or brackish water in a prairie formation of the Oligocene epoch of the Tertiary period of the Cenozoic era.
- Formation, Jackson.** A stage of the Eocene epoch of the Tertiary period of the Cenozoic era (or age of mammals) in geologic time.
- Frass.** The waste product of insect feeding; excrement.
- Fuels, flash.** Light fuels such as grasses and other dry materials that ignite readily, are consumed rapidly, and thus contribute to a rapid rate of fire spread.
- Fungus.** Any of a group of thallophytic plants known as the fungi.

G

Germination. The resumption of growth of a seed or spore; the development of a plant from a seed.

Germination, real. Percent of seed germinating.

Growth, old. (As applied in Forest Survey of the South.) Stands composed predominantly of saw-timber trees with the characteristics of the original, mature trees of the region.

Uncut. Old-growth stands from which less than 10 percent of the volume has been cut.

Partly cut. Old-growth stands from which at least 10 percent of the volume has been cut, but which are still characterized by residual trees from the old-growth forest.

Growth, second. (As applied in Forest Survey of the South.) Stands that have succeeded the original forest as a result of cutting or other causes. The smaller trees left after lumbering or available for a second cutting.

Sawlog size, uncut. Second-growth stands in which the sawlog-size trees contain at least 600 board feet per acre, and from which less than 10 percent of the board-foot volume has been cut.

Sawlog size, partly cut. Second-growth stands from which at least 10 percent of the board foot volume has been cut, but which still contain at least 400 board feet per acre in sawlog-size trees.

Under-sawlog size. Second-growth stands composed predominantly of under-sawlog-size trees at least 1 inch in diameter at breast height. In uncut stands the saw timber present contains less than 600 board feet per acre. In partly cut stands there is less than 400 board feet of saw timber per acre.

Gum. See *Oleoresin*.

Gutter. A V-shaped metal strip or trough inserted or attached obliquely immediately above the cup to direct the oleoresin into the container.

H

Hammock. In the southern United States, especially in Florida, an area characterized by hardwood vegetation, the soil containing more humus than that of the pine lands.

Hardpan. An indurated (hardened) or cemented soil horizon. The soil may have any texture and is compacted or cemented by iron oxide, organic material, silica, calcium carbonate, or other substances.

Hazard. A term applied to fuels that form a threat either of special fire-suppression difficulties if ignited, or of probable ignition because of their location.

Heat, specific. The ratio of the quantity of heat required to raise the temperature of a body one degree C. to that required to raise an equal mass of water one degree. Also the heat in calories required to raise the temperature of one gram of a substance one degree C.

Height, breast. A height of 4½ feet above the average ground surface or above the root collar; the diameters of unturpented trees are ordinarily measured at this height (abbreviation, d.b.h.).

High-grade. To deplete a forest stand by selecting and cutting the most valuable and highest quality trees.

Hogal. A turpentine tool similar to a *hack*, but with a strong elliptical blade like a puller blade, used instead of a broadax to slab off bark preparatory to seating a cup; also to cut the first streak. Syn. *Tree facer*.

Horizon, soil. A layer of soil approximately parallel to the land surface with more or less well-defined characteristics that have been produced through the operation of soil-building processes.

A-horizon. The upper horizon of the mineral soil, from which material has been removed by percolating waters. The horizon of eluviation. Commonly divided into a dark colored A₁ horizon containing a relatively high content of organic matter, and a light-colored A₂ horizon of maximum leaching.

- A₀-horizon.** Organic debris partly decomposed or matted. A combination of an F-layer, i.e., a fermentation layer, and an H-layer, i.e., a humified layer.
- Humus, raw.** See *Mor*.
- Hydrocarbon.** A compound containing only hydrogen and carbon.
- Hydro-mesophyte.** A plant intermediate between a hydrophyte and a mesophyte, but resembling more closely the mesophyte. Hydro-mesophytic, adj.
- Hydrophyte.** A plant that grows naturally under wet or moist conditions or which requires a large amount of moisture. Hydrophytic, adj.
- Hypha.** One of the threadlike elements of the mycelium of a fungus.
- Hypocotyl.** That portion of the stem or axis below the cotyledons in the embryo of a seed plant.
- Hypoderm, Hypodermis.** A layer of strengthening tissues beneath a thin external layer of cells known as the epidermis.

I

- Imbrication.** An overlapping of edges like that of tiles or shingles.
- Inflorescence.** A flower cluster, or the floral axis with its appendages; the mode of arrangement or development of the flowers.
- Ingrowth.** The volume or number of trees that has grown past an adopted lower limit of measurement during a specified period. Syn. *Recruits*.
- Inoculum.** Spores or tissues of a pathogen that serve to initiate disease in a plant.
- Integument.** A covering or coating structure or layer such as the envelope of an ovule.
- Internode.** The interval or part of a stem between two nodes or joints, where leaves or branch whorls are located.
- Intolerance.** Inability of a tree to develop and grow in the shade.

K

- Kraft.** A strong paper, usually brown, made from sulphate pulp.

L

- Land, crawfish.** Flat, poorly drained land inhabited by crawfish.
- Legume.** A leguminous plant; the fruit or seed of a leguminous plant—pods usually dehiscent into two parts having seeds attached along the ventral suture, as in the pea.
- Lightwood.** Pine wood, usually heartwood, heavy with natural deposits of resin, and from which most of the sapwood has been removed by decay. Syn. *Fatwood*, *Lighterwood*.
- Lignify.** To convert into wood; to become woody by a chemical alteration of constituents of the cell wall, converting them into lignin.
- Lignin.** A substance, or mixture of substances related physiologically to cellulose, and with it constituting the essential part of woody tissue.
- Limby.** (As applied to trees in Forest Survey in the South.) Limby trees have at least 12 feet of clear length and 30 to 49 percent of their total usable length practically free of limbs and indications of knots. (Compare with "smooth" and "rough.")
- Line, fire.** The narrow portion of a control line from which inflammable materials have been removed by scraping or digging down to mineral soil. See also *Firebreak*.
- Loss on ignition.** Loss in weight of soil as a result of burning out the organic and other combustible materials in a laboratory test.

M

- Management, sustained-yield.** Management of a given forest unit so that the annual or periodic yield of timber or other products can be maintained in perpetuity.
- Mast.** Nuts collectively; in the South it often refers to pine seeds or acorns as food for wildlife.

- Maturity, financial.** The age at which a tree or stand will no longer increase in value fast enough to earn a satisfactory rate of interest.
- Megasporangium.** A tiny capsule in which macrospores are produced.
- Meristele.** A leaf bundle in a protostelic stem, as that of the higher ferns; so-called because it contains elements of all the tissues of the stele, of which it is a portion.
- Meristem.** An embryonic or undifferentiated tissue, the cells of which are capable of active division.
- Meso-hydrophyte.** A plant intermediate in character between a mesophyte and a hydrophyte, but resembling more closely the hydrophyte. Mesophytic, adj.
- Mesophyll.** The green parenchyma between the epidermal layers of a foliage leaf.
- Mesophyte.** A plant that grows naturally under intermediate moisture conditions; Mesophytic, adj.
- Microfauna.** The minute animals characteristic of a given region or environment.
- Microsporangium.** A tiny capsule in which microspores are produced.
- Milacre.** A 1/1,000-acre sample plot used in surveys of reproduction or other vegetation, usually laid out in the form of 1/10-chain square.
- Mill, band.** A saw mill equipped with a band head saw.
- Mop-up (Mopping up).** The act of making a fire safe after it is controlled, such as extinguishing or removing burning material along or near the control line and felling snags.
- Mor.** A type of forest humus layer of unincorporated organic materials, usually matted or compacted or both, distinctly delimited from the mineral soil, unless the latter has been blackened by the washing in of organic matter. Syn. *Raw humus*.
- Mull.** A type of forest humus layer consisting of organic and mineral matter so mixed that the transition to the underlying layer is not sharp.
- Mycelium.** Network of filamentous cells forming typical vegetative structure of fungi, composed of hyphae.
- Mycorrhiza.** A rootlet of a higher plant modified through integral association with a fungus to form a constant structure which differs from either component but is attached to the root system and functions somewhat as a rootlet.

N

- Needles, secondary.** The familiar fascicled needle-like leaves of pines, developed later than the primary type of foliage.
- Node.** Point of origin of a leaf, branch, or protuberance on a stem at the location of a whorl of branches; a joint or knot.

O

- Occlusion.** The process of healing over or closing the wound made by cutting or breaking off a limb in pruning.
- Occlude.** To shut in by growing over; as a knot completely healed. To grow over a wound made by cutting or breaking off a limb in pruning.
- Oil, essential.** One of a group of volatile oils of characteristic odors. Distinguished from fatty oils by their volatility, nongreasiness, and nonsaponifying property. Many such oils occur in plants and impart a characteristic odor to flower, leaves, or wood. They consist of aromatic hydrocarbons, aldehydes, alcohols, ethers, acids, terpenes, or camphors.
- Oleoresin.** A natural combination of resinous substances and essential oils occurring in or exuding from plants. Upon distillation, the oleoresins obtained by chipping the living trees of *Pinus palustris* Mill. and *P. caribaea* Morelet yield the turpentine and rosin of the American naval stores industry. Syn. *Crude turpentine, dip, gum*.
- Ovary.** That part of the pistil which contains the ovules or immature fruit.
- Overstory.** That portion of the trees in a forest stand forming the upper crown cover. Syn. *Overwood*.

Overwood. See *Overstory*.

Ovule. The megasporangium of a seed plant; an immature seed.

P

Parenchyma. A tissue composed of thin-walled cells of essentially equal diameter that remain capable of cell division after maturity; a tissue that manufactures and stores oleo-resin and is capable of increases associated with wounding; sometimes called fundamental tissue. Parenchymatous, adj.

Pathogen. An organism capable of inducing disease.

Peak. The angle of bark and wood at the top of a turpentine face where the two most recent streaks meet.

Pen. A loose, rectangular stack of pulpwood or fuelwood in layers of two pieces each, of varying height and width; *to pen*, to stack wood in such piles or pens.

Percent, plant. Percent of clean seed sown which produces usable 1-year seedlings.

Period, rest. Years intervening between previous turpentine and resumption of such work on the same tree.

pH. A notation introduced by Sorensen to designate relatively weak acidity and alkalinity, such as is encountered in soils and biological systems. Technically, the common logarithm of the reciprocal of the hydrogen-ion concentration of a system. A pH of 7.0 indicates precise neutrality, higher values indicate alkalinity, and lower values acidity.

Phloem. The principal tissue of the fibrovascular system concerned with the translocation of elaborated foodstuffs; loosely, inner bark.

Photosynthesis. Synthesis of chemical compounds effected with the aid of radiant energy, especially light; the formation of carbohydrates, in constructive metabolism, from water and the carbon dioxide of the air in the chlorophyll-containing tissues of plants exposed to light.

Piedmont. A region lying or formed at the base of mountains. In the United States, the Piedmont Plateau comprises the moderately elevated region between the eastern foot of the Appalachian Mountains and the Atlantic Coastal Plain.

Pinene. Either of two hydrocarbons or terpenes, $C_{10}H_{16}$, principal component of oil of turpentine; Alpha pinene, optically active dextro-pinene and levo-pinene; Beta pinene, neopinene.

Pistil. Ovule- or seed-bearing organ of a seed plant; pistillate, adj.

Pit. A depression or unthickened spot in the wall of a cell; bordered pits have a marginal rim, in contrast to simple pits.

Pitch. A heavy viscous liquid or dark residue obtained by distillation of the tar derived from coal, wood, rosin, and petroleum oils. It consists of many organic compounds, chiefly hydrocarbons, differing according to its origin. Also tar reduced by evaporation or distillation, preferably not beyond half its original bulk.

Point, fiber-saturation. The moisture condition of wood in which the cell cavities are free from water but the cell walls are still saturated; usually occurs in most woods at a moisture content of 25 to 30 percent.

Pole. Timber in the round usually used to support telegraph, telephone, and power lines.

Pole, large. A tree 8 to 12 inches d.b.h.

Pole, small. A tree 4 to 8 inches d.b.h.—the size class of trees just above the sapling stage.

Pollen. The male fertilizing element of seed plants.

Pond. In the flatwoods terrain of the Southeast, a slight depression in the land surface, especially one with no outlet for standing water during wet periods. Most ponds are forested with pond cypress and hardwoods.

Presuppression. Those fire-control activities concerned with the organization, training, instruction, and management of the fire-control organization, and with the inspection and maintenance of fire-control improvements, equipment and supplies to insure effective fire suppression.

Protostele. Concentric bundle or central cylinder of vascular tissue of most roots and some stems; a simple and primitive form of stele.

Q

Quotient, form. The ratio of the diameter of the tree stem at one-half height inside bark to the basal diameter; or any ratio between diameters at heights other than one-half height to diameter at breast height.

R

Radicle. The downward growing point of a newly germinated seed; the embryo root that grows from the base of the hypocotyl.

Ray, wood. A strip or ribbon of tissue formed by the cambium and extending radially and horizontally among the vertical fibers.

Recruits. See *Ingrowth*.

Reproduction. Renewal of a forest or range by self-sown seeds, sprouts, rhizomes, etc., or seedlings or saplings of any origin. In the Federal Forest Survey of the South, restocking areas bearing 80 or more seedlings per acre that are less than 1 inch in diameter at breast height.

Reproduction, advance. Seedlings or saplings which have become established naturally in openings in the forest, or under the forest cover before reproduction fellings are begun.

Resin. See *Oleoresin*.

Resin ducts, canals, or passages. Tube-like intercellular structures in needles, shoots, or woody tissue, or clusters of parenchymatous cells, for the secretion and transport of resins, gums, etc.

Rosin. A hard, amber-colored product of pine oleoresin left after distilling-off the volatile oil of turpentine.

Rotation. The period of years required to establish and grow timber crops to a specified condition of maturity.

Rough. 1. An accumulation of all living and dead herbaceous vegetation, especially grasses, and forest litter, sometimes with the addition of underbrush, such as palmetto, gallberry, and waxmyrtle. The term is most often used to designate the ground cover of longleaf and slash pine forests when unburned for one or more years. 2. As applied to trees in the Forest Survey of the South, rough trees have less than 12 feet of clear length, or less than 30 percent of their total usable length practically free of limbs or knots. (Compare with "smooth" and "limby.")

Rule, density. An authorized and approved set of specifications of the Southern Pine Association under which southern yellow pine timbers may be graded.

Rupture, modulus of. The computed stress in the top and bottom fibers of a beam at the maximum load; a measure of the ability of a beam to support a slowly applied load for a short time.

S

Sapling. A young tree less than 4 inches in diameter breast high. The minimum size of saplings is usually though not invariably placed at 2 inches in diameter breast high. See *Pole*.

Saprophyte. A plant that obtains its food from dead organic matter. Saprophytic, adj.

Scrape. 1. Oleoresin from which volatile oils have evaporated. It accumulates on the scarified portion of a tree that is being bled and is removed at the end of the season's operations. 2. To collect scrape from the scarified portion of a tree that is being bled for oleoresin.

- Scrub.** Stunted trees or brush, often in dense stands.
- Seedbed.** 1. In natural reproduction, the soil or forest floor on which seed falls. 2. In nursery practice, a prepared area in which seed is sown.
- Septate.** Divided by partitions.
- Serrate.** Saw-edged; having relatively small teeth pointing forward or toward the apex.
- Sessile.** Sitting directly on base without a stalk.
- Shelterwood.** A method of obtaining natural reproduction under the temporary shelter of the seed-tree crown cover, by means of a series of cuttings that admit a gradually increasing supply of light to the seedlings.
- Site index.** The average height of dominant trees in a 50-year-old stand; a measure of site quality.
- Site quality.** The capacity of an area to produce forests, affected by the combined influence of biotic, climatic, and soil conditions.
- Slab.** The exterior portion of a log removed in sawing lumber.
- Smooth.** As applied to trees in Forest Survey of the South, smooth trees have 20 feet or more of clear length and also at least 50 percent of their total usable length practically free of limbs and indications of knots. (Compare with "rough" and "limby.")
- Stain, blue.** A deep-seated fungous discoloration of wood, predominantly bluish, but sometimes grayish, blackish, or brownish; a blemish that degrades select lumber with little or no effect on its strength; the work of various sap-stain fungi, confined almost exclusively to sapwood.
- Stamen.** The pollen-producing organ of a seed plant; usually consisting of an anther and a filament or stalk.
- Stand.** An aggregation of trees occupying a specific area and sufficiently uniform in composition (species), age arrangement and condition to be distinguishable from the forest on adjoining areas.
- Stele.** In wood anatomy, that part of the stem which includes the vascular system (xylem and phloem).
- Sterigma.** In fungi, a stalk from which a spore is abjoined.
- Stigma.** Portion of pistil which receives the pollen.
- Stoma.** A minute orifice in the epidermis of leaves, stems, etc., through which gaseous interchange is effected between the atmosphere and the interior of the organ. Stomata, pl.; stomatic, adj.
- Story, lower.** See *Understory*.
- Straw, pine.** Usually the dead and fallen pine needles that add to the "rough," the mulch on the forest floor, and the fire hazard.
- Streak.** The incision made when a tree is chipped in turpentineing.
- Structure, crumb.** A loose friable structure characteristic of soil in good tilth.
- Stumpage.** 1. The value of timber as it stands uncut in the woods. 2. In a general sense, the standing timber itself.
- Style.** Slender upper part of an ovary supporting stigma; attenuated part of a pistil or carpel between the ovary and the stigma.
- Succession.** The natural replacement of one plant community by another.
- Suppression.** All the work of extinguishing a fire, following its detection.
- Sweep.** A gradual bend in a log, pole, or pile, considered as a defect.
- Symbiont.** An organism living in symbiosis, a more or less intimate association or close union of dissimilar organisms. Ordinarily used in cases where the association is not harmful to either organism. Symbiotic, adj.

T

- Tar.** A thick, brown to black, viscous mixture of hydrocarbons and their derivatives obtained from the distillation of wood, coal, peat, etc.
- Terpene.** Any of a series of isomeric hydrocarbons, $C_{10}H_{16}$, prominent constituents of many volatile oils obtained by the distillation of plants, especially the conifers.

Timber, bled. Pine trees that have been turpented.

Timber, round. In turpentine, timber that has not been bled for oleoresin.

Tin. Any type of metal strip used to guide oleoresin from the face into the cup. See *Apron* and *Gutter*.

Tracheid. A long, tubelike xylem cell characterized by tapering, closed ends and by thickened, strongly lignified walls commonly having bordered pits. A water-conducting cell serving also for support in the wood of coniferous trees.

Transpiration. The process by which water vapor leaves a living plant and enters the atmosphere.

Tree, crop. Any tree forming or destined to form a part of the major forest crop.

Tree, nurse. A tree which protects or fosters the growth of another in youth.

Tree, wolf. A tree occupying more space than its silvicultural value warrants, curtailing better neighbors. A term usually applied to broad-crowned, short-stemmed trees.

Tube, pitch. Exudation of resin caused by insect infestation.

Turpentine. 1. The liquid product (essential oil) resulting from the distillation of oleoresin; also applied to oleoresin. 2. To tap a tree for oleoresin.

Type, cover. A forest type now occupying the ground, no implication being conveyed as to whether it is temporary or permanent.

Type, forest. A descriptive term used to group stands of similar composition and development due to ecological factors, by which they may be differentiated from other groups of stands.

Type, pure longleaf pine. As applied in the Forest Survey of the South, the longleaf pine type is called pure if 75 percent of the board-foot volume in sawlog-sized stands or 75 percent of the dominant and co-dominant trees in stands under sawlog size are longleaf pines.

U

Understory. That portion of the trees in a forest stand below the overstory. Syn. *Lower story*.

Unit (in naval stores). One 50-gallon barrel of turpentine and $3\frac{1}{3}$ 500-pound (gross) barrels of rosin.

Unit (in pulpwood). A stack of pulpwood 4 feet high, 8 feet long, and usually 5 feet wide. The width varies with the length of stick acceptable to various mills. The 4 by 5 by 8 unit contains 160 cubic feet.

V

Value, expectation. Expectancy value, the present worth of all estimated or expected future net earnings (discounted value); the capitalized net-income value.

Value, realization. Sales value minus costs of logging, hauling, and milling.

Vascular. Consisting of, or containing vessels adapted for transmission or circulation of fluid.

Ventral. Opposed to dorsal. The surface nearest the axis or substratum, as the upper or inner face of a leaf.

Viability. The potential capacity of seed to germinate.

Veteran. An old tree; sometimes used to denote a tree remaining from a former stand.

W

Whorl. A circle of three or more similar parts, such as flowers or branches, about the same point on an axis or central stem.

Windshake. A lengthwise separation of wood, which usually occurs between and parallel to the growth layers.

Wood, chemical. Wood cut or prepared primarily for the manufacture, distillation, or extraction of chemicals, charcoals, gases, naval stores, or other products of a nonfibrous nature.

Wood, compression. Abnormal wood formed on the lower sides of branches and inclined trunks of coniferous trees.

Wood-equilibrium-moisture content. That moisture condition which wood attains when exposed to constant conditions of temperature and relative humidity long enough to reach equilibrium.

X

Xerophyte. A plant that grows naturally in dry situations. Xerophytic, adj.; xerophilous, adj.

Xylem. Woody tissue; the lignified water-conducting, strengthening, and storage tissues of branches, stems, and roots. Syn. *Wood*.

Y

Yield, sustained. Management of a forest property in such a way that a volume of timber or other products sufficient for annual or periodic harvests will be available indefinitely.

BIBLIOGRAPHY

- (1) Anonymous.
1921. Money is actually lost in working small trees for turpentine and rosin. Naval Stores Rev. 30 (43): 14, 25.
- (2) _____
1929. Big longleaf seed crop in Alabama. U. S. Forest Serv. Forest Worker 5 (6): 3.
- (3) _____
1929. Making turpentine and rosins in the South seventy-eight years ago. (Article from DeBow's Southern & Western Review for September, 1851.) Gamble's Naval Stores Year Book 1929-30: 11-13.
- (4) _____
1929. What it cost to gather longleaf pine seed. Naval Stores Rev. 39 (4): 29.
- (5) _____
1934. Growth spurt made when right height reached. Sci. News Letter 25: 195.
- (6) Akerman, Alfred.
1928. Forest thinning. Ga. State Bd. Forestry Bul. 2, 10 pp., illus.
- (7) American Engineering and Industrial Standards.
1931. American tentative standard specifications for southern pine poles and American standard dimensions for southern pine poles. Approved Amer. Standards Assoc., 8 pp., illus. New York.
- (8) Anderson, D. A., and Balthis, R. F.
1944. Effect of annual fall fires on the taper of longleaf pine. Jour. Forestry 42: 518.
- (9) Anderson, R. T.
1937. Pruning of green branches of conifers. Quart. Jour. Forestry 31: 29-30, illus.
- (10) Andrews, E. F.
1917. Agency of fire in propagation of longleaf pines. Bot. Gaz. 64: 497-508, illus.
- (11) Arthur, J. C.
1906. New species of *Uredinieae*. V. Torrey Bot. Club Bul. 33: 519-520.
- (12) Ashe, W. W.
1894. The forests, forest lands, and forest products of eastern North Carolina. N. C. Geol. Survey Bul. 5, 128 pp., illus.
- (13) _____
1894. The longleaf pine and its struggle for existence. Elisha Mitchell Sci. Soc. Jour. 11: 1-16.
- (14) _____
1924. Economic waste in cutting small timber. South. Lumberman 117, (1525): 184-187, illus.
- (15) _____
1925. Cutting to increase the margin of profit. South. Lumberman 121 (1572 [i.e. 1573]): 39-40.
- (16) _____
1926. Profit in cutting timber for a permanent yield. South. Lumberman 123 (1597): 44, 46.
- (17) _____
1926. The establishment of longleaf pine. A review of Prof. Chapman's paper on the establishment of this species. 4 pp. Washington.

- (18) Bailey, L. H.
1923. The cultivated evergreens. 434 pp. New York.
- (19) Bailor, W. G.
1923. The longleaf pine. *Nature-Study Rev.* 19: 359-360.
- (20) Baird, P. K.
1931. Results of papermaking experiments with southern woods. *South. Lumberman* 143 (1804): 47-48.
- (21) Baker, H. L.
1929. Fire in the turpentine orchard. *Pine Inst. of Amer. Pine Tree Chem. Indus. Year Book* 1929: 55-57.
- (22) Barrett, L. I.
1929. Increased growth of longleaf pine left after logging. *South. Lumberman* 135 (1751): 39-40, illus.
- (23) Barton, L. V.
1928. Hastening the germination of southern pine seeds. *Jour. Forestry* 26: 774-785, illus.
- (24) ———
1935. Storage of some coniferous seeds. *Boyce Thompson Inst. Contrib.* 7: 379-404, illus.
- (25) Beal, J. A.
1932. Control of the turpentine borer in the naval stores region. *U. S. Dept. Agr. Cir.* 226, 19 pp., illus.
- (26) ———
1933. Temperature extremes as a factor in the ecology of the southern pine beetle. *Jour. Forestry* 31: 329-336.
- (27) Bennett, H. H.
1921. The soils and agriculture of the southern states. 399 pp. New York.
- (28) Berkley, E. E.
1934. Certain physical and structural properties of three species of southern yellow pine correlated with the compression strength of their wood. *Mo. Bot. Gard. Ann.* 21: 241-338, illus.
- (29) Berliner, J. F. T.
1941. Seasoning and treating southern lumber with urea. *South. Lumberman* 163 (2057): 189-195, illus.
- (30) Betts, H. S.
1909. Properties and uses of the southern pines. *U. S. Forest Serv. Cir.* 164, 30 pp.
- (31) ———
1917. The seasoning of wood. *U. S. Dept. Agr. Bul.* 552, 28 pp., illus.
- (32) ———
1919. Timber, its strength, seasoning, and grading. 234 pp. New York.
- (33) Bickford, C. A.
1942. The use of fire in the flatwoods of the Southeast. *Jour. Forestry* 40: 132-133.
- (34) ——— and Bruce, D.
1939. A tentative fire-danger meter for the longleaf-slash pine type. *U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper* 87, 5 pp., illus. [Processed.]
- (35) ——— and Bull, H.
1935. A destructive forest fire and some of its implications. *U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper* 46, 4 pp. [Processed.]
- (36) ——— and Curry, J. R.
1943. The use of fire in the protection of longleaf and slash pine forests. *U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper* 105, 22 pp., illus. [Processed.]

- (37) Bingham, F. F.
1929. The combination of reforestation, turpentine, and stock raising. Pine Inst. of Amer. Pine Tree Chem. Indus. Year Book 1929: 22-24.
- (38) Biswell, H. H., Shepherd, W. O., Southwell, B. L., and Boggess, T. S., Jr.
1943. Native forage plants of cutover forest lands in the coastal plain of Georgia. Ga. Coastal Plain Expt. Sta. Bul. 37, 43 pp., illus.
- (39) Biswell, H. H., Southwell, B. L., Stevenson, J. W., and Shepherd, W. O.
1942. Forest grazing and beef cattle production in the coastal plain of Georgia. Ga. Coastal Plain Expt. Sta. Cir. 8, 25 pp., illus.
- (40) Black, A. P., and Thronson, S. M.
1934. Oleoresin from individual trees of slash and longleaf pine. Indus. and Engin. Chem., Indus. Ed. 26: 66-69.
- (41) Blackman, M. W.
1922. Mississippi bark beetles. Miss. Agr. Expt. Sta. Tech. Bul. 11, 130 pp., illus.
- (42) Blackmon, G. H.
1943. The tung-oil industry. Bot. Rev. 9: 1-40.
- (43) Boyd, James.
1931-32. Fifty years in the southern pine industry. South. Lumberman 144 (1817): 59-67, illus.; 145 (1818): 23-34.
- (44) Bray, M. W., and Curran, C. E.
1933. White papers from southern pines. III. Pulping longleaf pine for strong, easy-bleaching pulp. Paper Trade Jour. 96 (6): 30-34.
- (45) —————
1937. Sulphate pulping of southern yellow pines: effect of growth variables on yield and pulp quality. Paper Trade Jour. 105 (20): 39-46, illus.
- (46) ————— and Paul, B. H.
1930. The evaluation of second-growth longleaf pine pulp wood from trees of varying rate of growth. South. Lumberman 141 (1793): 163-168, 170, illus.
- (47) Bray, W. L.
1901. Texas forests and the problem of forest management for the longleaf pine lands. Forester 7: 131-138, illus.
- (48) —————
1904. Forest resources of Texas. U. S. Bur. Forestry Bul. 47, 71 pp., illus.
- (49) Brewster, D. R.
1942. Possibilities of integrated utilization in the longleaf-slash pine type. Jour. Forestry 40: 134-137.
- (50) Brooks, E. M.
1943. Scrub oak, despised pest of forests in the South, now used in making brick. AT-FA Jour. 5 (4): 5.
- (51) Brown, N. C.
1919. Forest products, their manufacture and use. 471 pp., illus. New York.
- (52) Browne, D. J.
1832. The sylvia americana, or, a description of the forest trees indigenous to the United States, practically and botanically considered. 408 pp., illus. Boston.
- (53) Browne, F. L.
1933. Durability of paint on longleaf and shortleaf pine. South. Lumberman 146 (1844): 20-22, illus.
- (54) ————— and Hrubesky, C. E.
1931. Effect of resin in longleaf pine on the durability of house paints. Indus. and Engin. Chem., Indus. Ed. 23: 874-877.

- (55) Bruce, Donald.
1920. A proposed standardization of the checking of volume tables. *Jour. Forestry* 18: 544-548.
- (56) Brush, W. D.
[1919.] Size and quality of southern pine timber. 30 pp., illus. New Orleans.
- (57) Brust, A. W., and Berkley, E. E.
1935. The distribution and variations of certain strength and elastic properties of clear southern yellow pine wood. *Amer. Soc. Test. Mat. Proc.* 35 (2): 643-673, illus.
- (58) Bryant, R. C.
1909. Some notes on the yellow pine forests of central Alabama. *Soc. Amer. Foresters Proc.* 4: 72-83.
- (59) Buchholz, J. T.
1931. The pine embryo and the embryos of related genera. *Ill. Acad. Sci. Trans.* 23: 117-125, illus.
- (60) Buckman, Stanley.
1934. What is the relationship between durability and specific gravity of wood? *Jour. Forestry* 32: 725-728, illus.
- (61) Budd, A. W.
1937. Forest fires and fire weather in north Florida. *U. S. Forest Serv. Fire Control Notes* [1]: 241-242.
- (62) Bull, Henry.
1937. Tools and labor requirements for pruning longleaf pine. *Jour. Forestry* 35: 359-364.
- (63) —————
1943. Pruning practices in open-grown longleaf pine in relation to growth. *Jour. Forestry* 41: 174-179, illus.
- (64) Bullard, E. R.
1926. Thinks fungus no detriment. *Naval Stores Rev.* 36 (15): 16-17.
- (65) Bunker, P. S.
1927. Pine lumbering operations on a permanent basis. *South. Forestry Cong. Proc.* 9: 70-78.
- (66) —————
1928. Some notes on the longleaf pine. *Ala. Forest News* 2 (6): [3-4].
- (67) Burke, H. E.
1909. Injuries to forest trees by flat-headed borers. *U. S. Dept. Agr. Yearbook* 1909: 399-415, illus.
- (68) —————
1917. Flat-headed borers affecting forest trees in the United States. *U. S. Dept. Agr. Bul.* 437, 8 pp., illus.
- (69) Burleigh, T. D.
1938. The relation of birds to the establishment of longleaf pine seedlings in southern Mississippi. *U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper* 75, 5 pp., illus. [Processed.]
- (70) Busck, August.
1915. The European pine-shoot moth; a serious menace to pine timber in America. *U. S. Dept. Agr. Bul.* 170, 11 pp., illus.
- (71) Buttrick, P. L.
1914. Notes on germination and reproduction of longleaf pine in southern Mississippi. *Forestry Quart.* 12: 532-537, illus.
- (72) —————
1915. Commercial uses of longleaf pine. *Amer. Forestry* 21: 896-908, illus.
- (73) Caldwell, [G. W.]
1904. The story of the southern evergreens. *Country Life in Amer.* 7: 171-176, illus.

- (74) Camp, P. D.
1932. A study of range cattle management in Alachua County, Florida. Fla. Agr. Expt. Sta. Bul. 248, 28 pp., illus.
- (75) Carr, A. S.
1926. Intensive working main cause. *Naval Stores Rev.* 36 (15): 16.
- (76) Carrier, Lyman.
1923. The beginnings of agriculture in America. 323 pp. New York.
- (77) Carter, J. F.
1924. Use of longleaf pine stumps in paper making. *South. Lumberman* 117 (1525): 149-151, illus.
- (78) ———
1925. Extracting profits from pine stumps. *South. Lumberman* 121 (1573 [i.e., 1574]): 43-44.
- (79) Cary, Austin.
1921-33. Studies on flow of gum in relation to profit in the naval stores industry. [46 papers.] In *Naval Stores Rev.*, v. 31, No. 34—v. 42, No. 8. [Reprinted, in condensed form, in *Naval Stores Rev.*, v. 43, No. 16-24, 1933.]
- (80) ———
1925. Forestry with the Jackson Lumber Company. *South. Lumberman* 121 (1576 [i.e., 1577]): 158-159.
- (81) ———
1929. Good naval-stores practice . . . based on studies of the Forest Service and the experience of successful operators. U. S. Dept. Agr. Leaflet 41, 4 pp., illus.
- (82) ———
1932. On the recent drought and its effects. *Naval Stores Rev.* 42 (17): 14-15; (18): 14-15, 20; (19): 14-15, 18-19.
- (83) ———
1932. Some relations of fire to longleaf pine. *Jour. Forestry* 30: 594-601, illus.
- (84) ———
1933. Follow-up on the drought effects. *Naval Stores Rev.* 42 (50): 8, 10, 12; (51): 8, 12.
- (85) Catesby, Mark.
1731-43. The natural history of Carolina, Florida, and the Bahama Islands. 2 v., illus. London.
- (86) Ceremello, P. J.
1942. Carpet grass sod on forest roads gives forest better fire protection. *AT-FA Jour.* 4 (5): 12.
- (87) Chadwick, T. C., and Palkin, Samuel.
1941. Composition of American gum turpentine exclusive of the pinenes. U. S. Dept. Agr. Tech. Bul. 749, 16 pp., illus.
- (88) Champion, H. G.
1924. Seed-production of pines tapped for resin. *Indian Forester* 50: 445.
- (89) Chapman, A. D., and Scheffer, T. C.
1940. Effect of blue stain on specific gravity and strength of southern pine. *Jour. Agr. Res.* 61: 125-133.
- (90) Chapman, C. S.
1905. A working plan for forest lands in Berkeley County, South Carolina. U. S. Dept. Agr. Bur. Forestry Bul. 56, 62 pp., illus.
- (91) Chapman, H. H.
1909. A method of studying growth and yield of longleaf pine applied in Tyler Co., Texas. *Soc. Amer. Foresters Proc.* 4: 207-220.
- (92) ———
1909. An experiment in logging longleaf pine. *Forestry Quart.* 7: 385-395.

- (93) 1909. Discussion of the method of logging longleaf pine in two cuttings. Amer. Lumberman, No. 1781, pp. 46-47.
- (94) 1912. Forest fires and forestry in the southern states. Amer. Forestry 18: 510-517, illus.
- (95) 1916. Top diameters as affecting the frustum form factor for longleaf pine. Soc. Amer. Foresters Proc. 11: 185-191.
- (96) 1920. Seed trees on longleaf pine lands in the South. Lumber Trade Jour. 77 (11): 17-19.
- (97) 1922. A new hybrid pine (*Pinus palustris* \times *Pinus taeda*). Jour. Forestry 20: 729-734, illus.
- (98) 1923. The causes and rate of decadence in stands of virgin longleaf pine. Lumber Trade Jour. 84 (6): 11, 16-17.
- (99) 1925. Seed trees for profit or seed trees for show. Lumber Trade Jour. 87 (2): 18.
- (100) 1926. Factors determining natural reproduction of longleaf pine on cut-over lands in LaSalle Parish, La. Yale Univ. School Forestry Bul. 16, 44 pp., illus. New Haven, Conn.
- (101) 1931. Successful reproduction of longleaf pine on Norfolk soils. U. S. Forest Serv. Forest Worker 7 (5): 17.
- (102) 1932. Is the longleaf type a climax? Ecology 13: 328-334.
- (103) 1932. Some further relations of fire to longleaf pine. Jour. Forestry 30: 602-604.
- (104) 1936. Effect of fire in preparation of seedbed for longleaf pine seedlings. Jour. Forestry 34: 852-854.
- (105) 1936. Effect of ground cover on growth rate of longleaf pine seedlings. Jour. Forestry 34: 535.
- (106) 1938. Birds and longleaf pine reproduction. Jour. Forestry 36: 1246-1247.
- (107) 1939. Further comments on yield tables for southern pines. Jour. Forestry 37: 418-420.
- (108) 1940. Forest fires in 1938. Jour. Forestry 38: 64-65.
- (109) 1941. Note on the history of a stand of pine timber at Urania, La. Jour. Forestry 39: 951-952.
- (110) 1942. Cost of controlled burning in longleaf pine, Urania, La. Jour. Forestry 40: 808-809.
- (111) 1943. A 27-year record of annual burning versus protection of longleaf pine reproduction. Jour. Forestry 41: 71-72.

- (112) ————
1944. Fire and pines, a realistic appraisal of the role of fire in reproducing and growing southern pines. *Amer. Forests* 50 (2): 62-64, 91-93, illus.
- (113) ———— and Bulchis, Robert.
1940. Increased growth of longleaf pine seed trees at Urania, La., after release cutting. *Jour. Forestry* 38: 722-726, illus.
- (114) Chapman, R. A.
1938. The effect of origin of stand on the site index of longleaf pine. *Jour. Forestry* 36: 75-77, illus.
- (115) Cline, McGarvey.
1912. Strength values for structural timbers. U. S. Forest Serv. Cir. 189, 8 pp.
- (116) ———— and Heim, A. L.
1912. Tests of structural timbers. U. S. Forest Serv. Bul. 108, 123 pp., illus.
- (117) Cloud, O. N.
1928. Where are you going, longleaf? *South. Lumberman* 133 (1734): 136-138, illus.
- (118) Cocks, R. S.
1925. Catalogue of trees growing naturally in the vicinity of Sardis, Dallas County, Alabama. *Arnold Arboretum Jour.* 6: 189-195.
- (119) Coile, T. S.
1936. The effect of rainfall and temperature on the annual radial growth of pine in the southern United States. *Ecol. Monog.* 6: 533-562, illus.
- (120) Coker, W. C., and Totten, H. R.
1934. Trees of the southeastern states, including Virginia, North Carolina, South Carolina, Georgia, and northern Florida. 399 pp., illus. Chapel Hill, N. C.
- (121) Collingwood, G. H.
1927. Pines of progress, the story of the Great Southern Lumber Company's industrial community founded on faith and action in growing forests. *Amer. Forests and Forest Life* 33: 525-529, illus.
- (122) Conarro, R. M.
1942. The place of fire in southern forestry. *Jour. Forestry* 40: 129-131.
- (123) Cooper, J. G.
1861. On the forests and trees of Florida and the Mexican boundary. *Smithsn. Inst. Ann Rpt.* 1860: 439-442.
- (124) Cossitt, F. M.
1938. Cultural practices in southern forest nurseries. 21 pp. U. S. Forest Serv. Southern Region, Atlanta, Ga. [Processed.]
- (125) Coulter, J. M., and Rose, J. N.
1886. Synopsis of North American pines based upon leaf-anatomy. *Bot. Gaz.* 2: 256-262, 302-309, illus.
- (126) Cox, W. K.
1930. Studies of logging operations in the southern states. *South. Lumberman* 40 [i.e., 141] (1790): 37-39.
- (127) Craighead, F. C.
1927. The turpentine borer on the Florida National Forest. U. S. Forest Serv. *Forest Worker* 3 (4): 11-12.
- (128) ————
1928. Interrelation of tree-killing barkbeetles (*Dendroctonus*) and blue stains. *Jour. Forestry* 26: 886-887.
- (129) ———— and Middleton, William.
1930. An annotated list of the important North American forest insects. U. S. Dept. Agr. Misc. Pub. 74, 31 pp.

- (130) ——— and St. George, R. A.
1930. A new technique in tree medication for the control of bark beetles. *Science* 72: 433-435.
- (131) Cruikshank, J. W.
1937. Volumes on an average acre in the various units of the pine-hardwood region west of Mississippi. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 26, 29 pp. [Processed.]
- (132) ———
1939. Forest resources of southwest Louisiana. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 43, 38 pp., illus. [Processed.]
- (133) ——— and Eldredge, I. F.
1939. Forest resources of southeastern Texas. U. S. Dept. Agr. Misc. Pub. 326, 37 pp., illus.
- (134) Cuno, J. B.
1935. Power pruning. *Jour. Forestry* 33: 753-754, illus.
- (135) Curran, C. E.
1936. Pulpwood quality of southern pine as related to the requirements of newsprint production. *Jour. Forestry* 34: 198-202.
- (136) ———
1938. Relation of growth characteristics of southern pine to its use in pulping. *Jour. Forestry* 36: 576-581.
- (137) Currie, R. P.
1905. Catalogue of the exhibit of economic entomology at the Lewis and Clark Centennial Exposition, Portland, Oregon, 1905. U. S. Bur. Ent. Bul. (n. s.) 53, 127 pp.
- (138) Curtis, J. D.
1936. A method of pruning dead branches. *Forestry Chron.* 12: 291-299, illus.
- (139) Curtis, J. G.
1931. Longleaf pine—pride of the South. *Home Geog. Monthly* 1 (6): 13-18.
- (140) Dallimore, William, and Jackson, A. B.
1931. A handbook of *Coniferae* including *Ginkgoaceae*. Ed. 2, 581 pp., illus.
- (141) Davis, E. M.
1927. The density of southern pine, its significance in terms of properties and grades. *South. Lumberman* 129 (1681): 161-164, illus.
- (142) Davis, W. W.
1904. The yellow-pine industry in the South. *Rev. of Reviews* [New York] 29: 443-450, illus.
- (143) Dearness, John.
1928. New and noteworthy fungi—V. *Mycologia* 20: 235-246.
- (144) Deen, J. L.
1933. Effect of weight class on germination in longleaf pine. *Jour. Forestry* 31: 434-435.
- (145) Demmon, E. L.
1926. Fire damage in virgin southern pine. *South. Lumberman* 124 (1615): 47 illus.
- (146) ———
1928. What the forest fires of 1927 did to the pines on Georgia cut-over lands. *Naval Stores Rev.* 38 (35): 14-15.
- (147) ———
1929. Fires and forest growth. *Amer. Forests and Forest Life* 35: 273-276, 296, illus.
- (148) ———
1930. Relation of forest research to the naval stores industry. *Jour. Forestry* 28: 515-520.

- (149) _____
1935. The silvicultural aspects of the forest-fire problem in the longleaf pine region. *Jour. Forestry* 33: 323-331.
- (150) _____
1936. Influence of forest practice on the suitability of southern pine for newsprint. *Jour. Forestry* 34: 202-210.
- (151) _____
1936. Rate of formation of heartwood in southern pines. *Jour. Forestry* 34: 775-776.
- (152) _____ and Hadley, E. W.
1926. [Review of] "Factors determining natural reproduction of longleaf pine on cut-over lands in LaSalle Parish, Louisiana." By H. H. Chapman, Yale University School of Forestry, Bulletin No. 16. *Jour. Forestry* 24: 807-811.
- (153) Doi, T., and Morikawa, K.
1929. An anatomical study of the leaves of the genus *Pinus*. *Kyushu Imp. Univ. Dept. Agr. Jour.* 2: 149-198, illus.
- (154) Drolet, George.
1919. Turpentine orcharding effect on longleaf timber. *Jour. Forestry* 17: 832-834.
- (155) Dudley, P. H.
1887. Structure of certain timber-ties; behavior and causes of their decay in the road-bed. *U. S. Dept. Agr. Div. Forestry Bul.* 1: 31-65.
- (156) Dunlap, Frederick.
1912. The specific heat of wood. *U. S. Forest Serv. Bul.* 110, 28 pp., illus.
- (157) Dunstan, C. E.
1910. Preliminary examination of the forest conditions of Mississippi. *Miss. State Geol. Survey Bul.* 7, 76 pp., illus.
- (158) Edgerton, C. W., and Moreland, C. G.
1924. Department of Plant Pathology. *La. Agr. Expt. Sta. Ann. Rpt.* 35: 28-30.
- (159) Eldredge, I. F.
1911. Fire problem on the Florida National Forest. *Soc. Amer. Foresters Proc.* 6: 166-170.
- (160) _____
1914. The administration of a national forest for naval stores. *Soc. Amer. Foresters Proc.* 9: 310-326.
- (161) _____
1928. Fireproofing the Georgia woods. *Amer. Forests and Forest Life* 34: 221-223, illus.
- (162) _____
1929. Suwanee Forest. *Ga. State Col. Agr. Forestry Club Cypress Knee* 7: 66-68, illus.
- (163) _____
1929. The management of industrial forests in the naval stores belt. *Pine Inst. of Amer. Pine Tree Chem. Indus. Year Book* 1929: 52-54.
- (164) _____
1930. Fire protection in a large forest. *Ga. Forest Serv. Bul.* 11: 45-50.
- (165) _____
1931. Management of southern pine for naval stores. *Jour. Forestry* 29: 328-333.
- (166) _____
1935. Administrative problems in fire control in the longleaf-slash pine region of the South. *Jour. Forestry* 33: 342-345.

- (167) ————
1937. Volumes on average acres in the principal units of the naval-stores region. A progress report by the Southern Forest Survey. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 29, 17 pp., illus. [Processed.]
- (168) ————
1942. Forestry in the future of the South. Jour. Forestry 40: 140-142.
- (169) Emerson, F. V.
1919. The southern longleaf pine belt. Geog. Rev. 7: 81-90, illus.
- (170) Faulks, E. B.
1938. Forest resources in the longleaf pine region of Mississippi and east Louisiana. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 39, 34 pp., illus. [Processed.]
- (171) Ferguson, M. C.
1904. Contributions to the knowledge of the life history of *Pinus*, with special reference to sporogenesis, the development of the gametophytes and fertilization. Wash. Acad. Sci. Proc. 6: 1-202.
- (172) Fernow, B. E.
1892. Southern timber resources, the supply of the future. Mfrs. Rec. 21 (19): 27-29, illus.
- (173) ————
1892. The southern pines. Mfrs. Rec. 21 (21): 25-26.
- (174) ————
1893. Effect of turpentine gathering on the timber of longleaf pine. U. S. Dept. Agr. Div. Forestry Cir. 9, 1 p.
- (175) ————
1893. The longleaf pine. (*Pinus palustris* Mill.) Brief account of the species—its botanical and technical characteristics and distribution. U. S. Dept. Agr. Forestry Div. Bul. 8 (Timber Physics, Pt. II), pp. 14-21.
- (176) ————
1896. Southern pine—mechanical and physical properties. U. S. Dept. Agr., Div. Forestry Cir. 12, 12 pp.
- (177) Fogarty, F. L.
1929. The destructive distillation of pine wood. Naval Stores Rev. 39 (37): 6.
- (178) Folweiler, A. D.
1932. Forest management as conducted by L. H. Howell, at Panama City, Fla. Naval Stores Rev. 42 (39): 3, 10.
- (179) Forbes, R. D.
1919. A forest policy for Louisiana. Jour. Forestry 17: 503-514.
- (180) ————
1921. The why and the how of forestry in Louisiana. La. Dept. Conserv. Bul. 7, 40 pp., illus.
- (181) ————
1926. Diameter limit cutting in southern pine. South. Lumberman 122 (1580 [i.e., 1581]): 36-37.
- (182) ————
1930. Timber growing and logging and turpentine practices in the southern pine region. U. S. Dept. Agr. Tech. Bul. 204, 115 pp., illus.
- (183) ———— and Bruce, Donald.
1930. Rate of growth of second-growth southern pines in full stands. U. S. Dept. Agr. Cir. 124, 77 pp., illus.
- (184) Foster, J. H.
1912. Forest conditions in Louisiana. U. S. Forest Serv. Bul. 114, 39 pp., illus.

- (185) ——— Krausz, H. B., and Johnson, G. W.
1917. Forest resources of eastern Texas. Tex. Dept. Forestry Bul. 5, 57 pp., illus. (Tex. Agr. Col. Bul., Ser. 3, v. 3, No. 10.)
- (186) ——— and Leidigh, A. H.
1917. General survey of Texas woodlands. Tex. Dept. Forestry Bul. 3, 47 pp., illus. (Tex. Agr. Col. Bul., Ser. 3, v. 3, No. 9.)
- (187) Fowells, H. A., and Stephenson, R. E.
1934. Effect of burning on forest soils. Soil Sci. 38: 175-181.
- (188) Friend, R. B., and West, A. S., Jr.
1933. The European pine shoot moth (*Rhyacionia buoliana* Schiff.) with special reference to its occurrence in the Eli Whitney Forest. Yale Univ. School Forestry Bul. 37, 65 pp., illus.
- (189) Frothingham, E. H., and Nelson, R. M.
1944. South Carolina forest resources and industries. U. S. Dept. Agri. Misc. Pub. 552, 72 pp., illus.
- (190) Gamble, Thomas.
1921. The production of naval stores in the United States. In Gamble, T., Naval Stores; history, production, distribution, and consumption, pp. 77-87, illus. Savannah, Ga.
- (191) Gano, Laura.
1917. A study in physiographic ecology in northern Florida. Bot. Gaz. 63: 337-372, illus.
- (192) Garren, K. H.
1943. Effects of fire on vegetation of the southeastern United States. Bot. Rev. 9: 617-654
- (193) Garrison, P. M.
1928. Forestry and utilization as practiced by the Great Southern Lumber Company. Ames Forester 16: 65-70, illus.
- (194) ———
1929. Practicing industrial forestry in southern pine. Ga. State Col. Agr. Forestry Club Cypress Knee 7: 63-65, illus.
- (195) Garver, R. D., and Cuno, J. B.
1935. Selective logging in the loblolly and longleaf pine forests of South Carolina. 14 pp., illus. Madison, Wis. (U. S. Forest Serv. Forest Prod. Lab.) [Processed.]
- (196) Geer, W. C.
1907. Wood distillation. U. S. Forest Serv. Cir. 114, 8 pp.
- (197) Gemmer, E. W.
1928. Black ants as destroyers of longleaf pine seedlings. Naval Stores Rev. 38 (7): 25.
- (198) ———
1928. The root system of a longleaf pine. Sci. Monthly 27: 384, illus.
- (199) ———
1932. Well-fed pines produce more cones. U. S. Forest Serv. Forest Worker 8 (5): 15.
- (200) ———
1933. Choctawhatchee planting tool. Jour. Forestry 31: 598-599, illus.
- (201) ——— Maki, T. E., and Chapman, R. A.
1940. Ecological aspects of longleaf pine regeneration in south Mississippi. Ecology 21: 75-86, illus.
- (202) Georgia Forest Service.
1927. Report of forest fire line demonstration held at Waycross, Ga., Aug. 31st and Sept. 1st, 1927. Ga. Forest Serv. Leaflet 3, 20 pp., illus.

- (203) Gerry, Eloise.
1916. Fiber measurement studies. A comparison of tracheid dimensions in longleaf pine and Douglas fir, with data on the strength and length, mean diameter and thickness of wall of the tracheids. (Abstract.) *Science* 43: 360.
- (204) ————
1921. The production of crude "gum" by the pine tree. In Gamble, T., *Naval Stores; history, production, distribution, and consumption*, pp. 147-153, illus. Savannah, Ga.
- (205) ————
1922. Oleoresin production: a microscopic study of the effects produced on the woody tissues of southern pines by different methods of turpentineing. U. S. Dept. Agr. Bul. 1064, 46 pp., illus.
- (206) ————
1923. Recent observations on the effects of turpentineing on the structure of second-growth slash and longleaf pines. *Jour. Forestry* 21: 236-241, illus.
- (207) ————
1923. The goose and the golden eggs, or, naval stores production a la Aesop. *South. Lumberman* 112 (1456): 36-38, illus.
- (208) ————
1925. Effect of height of chipping on oleoresin production. *Jour. Agr. Res.* 30: 81-93, illus.
- (209) ————
1927. Wood and oleoresin formation in turpentineed longleaf pine as affected by spring forest fire. (Abstract.) *Amer. Jour. Bot.* 14: 621.
- (210) ————
1930. The responses of longleaf pine (*Pinus palustris* Miller) defoliated by fire and turpentineed for three years. (Abstract.) *American Jour. Bot.* 17: 1041.
- (211) ————
1931. Improvement in the production of oleoresin through lower chipping. U. S. Dept. Agr. Tech. Bul. 262, 24 pp., illus.
- (212) ————
1931. Oleoresin production from longleaf pine defoliated by fire. *Jour. Agr. Res.* 43: 827-836, illus.
- (213) ———— and Hall, J. A.
1935. Biochemical phases of oleoresin production. *Plant Physiol.* 10: 537-543, illus.
- (214) Gillican, C. C.
1926. Cupping timber low in vitality causes dry facing. *Naval Stores Rev.* 36 (16): 22.
- (215) Girard, J. W.
1933. Volume tables for Mississippi bottomland hardwoods and southern pines. *Jour. Forestry* 31: 34-41.
- (216) ———— and Gevorkiantz, S. R.
1939. Timber cruising. 160 pp. [Washington, D. C.] (U. S. Forest Serv.) [Processed.]
- (217) Gomberg, Moses.
1893. A chemical study of the resinous contents and their distribution in trees of the longleaf pine, before and after tapping for turpentine. U. S. Dept. Agr. Forestry Div. Bul. 8: 34-49, illus.
- (218) Grabow, R. H.
1923. Suitability of various American woods for pulp and paper making. *Jour. Forestry* 21: 462-474.

- (219) Graham, E. H.
1944. Natural principles of land use. 274 pp., illus. New York.
- (220) Greene, S. W.
1931. The forest that fire made. *Amer. Forests* 37: 583-584, 618, illus.
- (221) ———
1935. Effect of annual grass fires on organic matter and other constituents of virgin longleaf pine soils. *Jour. Agr. Res.* 50: 809-822.
- (222) ———
1935. Relation between winter grass fires and cattle grazing in the longleaf pine belt. *Jour. Forestry* 33: 338-341.
- (223) Haasis, F. W.
1928. Germinative energy of lots of coniferous-tree seed, as related to incubation temperature and to duration of incubation. *Plant Physiol.* 3: 365-412, illus.
- (224) Hall, S. J.
1928. Scientific forest management as applied to turpentine production. *South. Lumber Jour. (N. S.)* 32 (4): 43-45.
- (225) ———
1929. Forest management for the turpentine operator. *Naval Stores Rev.* 39 (13): 16-17, 21, illus.
- (226) ———
1929. The landowner and forest management. *Naval Stores Rev.* 39 (34): 12.
- (227) ———
1930. Permanent forest industry being developed in the South. *Mfrs. Rec.* 98 (12): 52-53, illus.
- (228) ———
1931. The application of research to forest management. *South. Lumberman* 142 (1798): 49-50.
- (229) ———
1939. The place of naval stores operations in forest management. *Jour. Forestry* 37: 544-546.
- (230) Hall, W. L., and Maxwell, Hu.
1911. Uses of commercial woods of the United States: II. Pines. *U. S. Forest Serv. Bul.* 99, 96 pp.
- (231) Hall, W. M., and Maxwell, H.
1911. Longleaf pine—a great structural timber. *Cassier's Mag.* 40: 661-667.
- (232) Hallauer, F. J., Hall, J. A., Brown, F. L., Curran, C. E., and Baird, P. K.
1941. Timber requirements for naval stores, an analysis of production and consumption of turpentine and rosin. A progress report of the Forest Survey, requirements phase. 95 pp., illus. [Washington, D. C.] (U. S. Dept. Agr., Forest Serv.) [Processed.]
- (233) Hammond, Harry, ed.
1883. South Carolina. Resources and population. Institutions and industries. Pub. by the State Board of Agriculture of South Carolina. 726 pp., illus. Charleston, S. C.
- (234) Hardtner, H. E.
1918. Reforestation and controlled burnings. *Lumber Trade Jour.* 74 (10): 35-36.
- (235) ———
1923. Forestry for the private landowner. *South. Forestry Cong. Proc.* 5: 72-76.
- (236) ———
1932. Forestry at Urania, Louisiana. *Jour. Forestry* 30: 310-311.
- (237) ———
1935. A tale of a root—a root of a tale or, root hog or die. *Jour. Forestry* 33: 351-357.

- (238) Harlow, W. M.
1931. The identification of the pines of the United States, native and introduced, by needle structure. N. Y. State Coll. Forestry, Syracuse Univ. Tech. Pub. 32, 21 pp., illus.
- (239) Harper, R. M.
1900. Notes on the flora of south Georgia. Torrey Bot. Club Bul. 27: 413-436.
- (240) ———
1906. A phytogeographical sketch of the Altamaha Grit region of the coastal plain of Georgia. N. Y. Acad. Sci. Ann. 17: 1-414, illus.
- (241) ———
1911. The relation of climax vegetation to islands and peninsulas. Torrey Bot. Club Bul. 38: 515-525.
- (242) ———
1913. A defense of forest fires. Lit. Digest 47: 208.
- (243) ———
1913. Geographical report, including descriptions of the natural divisions of the State, their forests and forest industries, with quantitative analyses and statistical tables. Ala. Geol. Survey Monog. 8, 228 pp., illus.
- (244) ———
1913. The forest regions of Alabama. South. Lumberman 68 (915): 31-32.
- (245) ———
1913. The forest regions of Mississippi in relation to the lumber industry. South. Lumberman 70 (935): 27-28, illus.
- (246) ———
1913. The forest resources of Alabama. Amer. Forestry 19: 657-670, illus.
- (247) ———
1914. A superficial study of the pine-barren vegetation of Mississippi. Torrey Bot. Club Bul. 41: 551-567, illus.
- (248) ———
1914. Geography and vegetation of northern Florida. Fla. State Geol. Survey Ann. Rpt. 6: 163-437, illus.
- (249) ———
1914. The coniferous forests of eastern North America. Pop. Sci. Monthly 85: 338-361, illus.
- (250) ———
1923. Some recent extensions of the known range of *Pinus palustris*. Torreya 23: 49-51.
- (251) ———
1928. Economic botany of Alabama, part 2. Catalogue of the trees, shrubs and vines of Alabama, with their economic properties and local distribution. Ala. Geol. Survey Monog. 9, 357 pp.
- (252) ———
1929. Forests and trees of Georgia. Ga. State Hort. Soc. Proc. 53: 45-54.
- (253) ———
1943. Forests of Alabama. Ala. Geol. Survey Monog. 10, 230 pp., illus.
- (254) Harper, V. L.
1928. Small trees make more scrape than big trees. Naval Stores Rev. 38 (3): 9.
- (255) ———
1931. French face experiments in turpentineing. Jour. Forestry 29: 225-232, illus.
- (256) ———
1937. Fire research in the Lower South. U. S. Forest Serv. Fire Control Notes [1]: 229-237.

- (257) ————
1937. The effect of turpentine on the growth of longleaf and slash pine. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 64, 4 pp. [Processed.]
- (258) ————
1944. Effect of fire on gum yields of longleaf and slash pines. U. S. Dept. Agr. Cir. 710, 42 pp., illus.
- (259) ———— and Liefeld, T. A.
1938. A new day in the naval stores industry. Jour. Forestry 36: 1128-1130.
- (260) ———— and Wyman, Lenthall.
1936. Variations in naval-stores yields associated with weather and specific days between chippings. U. S. Dept. Agr. Tech. Bul. 510, 35 pp., illus.
- (261) Harper, W. B.
1907. The utilization of wood waste by distillation. 156 pp., illus. St. Louis.
- (262) ————
1921. Development of the wood turpentine and wood rosin industry. In Gamble, T., Naval Stores; history, production, distribution, and consumption, pp. 245-246. Savannah, Ga.
- (263) Hartman, G. B.
1922. The Calcasieu pine district of Louisiana. Ames Forester 10: 63-68.
- (264) Hatt, W. K.
1904. Progress report on the strength of structural timber. U. S. Bur. Forestry Cir. 32, 28 pp.
- (265) ————
1907. Second progress report on the strength of structural timber. U. S. Forest Serv. Cir. 115, 39 pp.
- (266) Hauch, L.
1934. Deviation capacity of forest trees. Jour. Forestry 32: 729-733.
- (267) Hawley, L. F.
1913. Wood turpentines; their analysis, refining and composition. U. S. Forest Serv. Bul. 105, 69 pp., illus.
- (268) ———— and Palmer, R. C.
1912. Distillation of resinous wood by saturated steam. U. S. Forest Serv. Bul. 109, 31 pp.
- (269) ———— and Wise, L. E.
1926. The chemistry of wood. 334 pp., illus. New York. (Amer. Chem. Soc. Monog.)
- (270) Hayes, R. W., and Wakeley, P. C.
1929. Survival and early growth of planted southern pine in southeastern Louisiana. La. State Univ. Bul., new series, v. 21, No. 3, Pt. 2, 48 pp., illus.
- (271) Headley, Roy.
1939. Lessons from larger fires of 1938. U. S. Forest Serv. Fire Control Notes 3 (4): 30-45.
- (272) Hedgcock, G. G.
1929. *Septoria acicola* and the brown-spot disease of pine needles. Phytopathology 19: 993-999, illus.
- (273) ———— and Hahn, G. G.
1922. Two important pine cone rusts and their new cronal stages. Phytopathology 12: 109-122, illus.
- (274) Henegar, M. E.
1943. Gum naval stores timber land use; information and suggestions. 34 pp. Brunswick, Ga.
- (275) Hepting, G. H.
1942. Reducing losses from tree diseases in eastern forests and farm woodlands. U. S. Dept. Agr. Farmers' Bul. 1887, 22 pp., illus.

- (276) Herty, C. H.
1903. A new method of turpentine orcharding. U. S. Bur. Forestry Bul. 40, 43 pp., illus.
- (277) ———
1911. Relation of light chipping to the commercial yield of naval stores. U. S. Forest Serv. Bul. 90, 36 pp., illus.
- (278) ———
1916. The turpentine industry in the southern states. Franklin Inst. Jour. 181: 339-367, illus.
- (279) Heyward, Frank.
1933. The root system of longleaf pine on the deep sands of western Florida. Ecology 14: 136-148, illus.
- (280) ———
1934. Needle browning in longleaf and slash pines during the late summer. Naval Stores Rev. 44 (31): 12.
- (281) ———
1936. Soil changes associated with forest fires in the longleaf pine region of the South. Amer. Soil Survey Assoc. Bul. 17: 41-42. [Processed.]
- (282) ———
1937. The effect of frequent fires on profile development of longleaf pine forest soils. Jour. Forestry 35: 23-27, illus.
- (283) ———
1938. Soil temperatures during forest fires in the longleaf pine region. Jour. Forestry 36: 478-491, illus.
- (284) ———
1939. Some moisture relationships of soils from burned and unburned longleaf pine forests. Soil Sci. 47: 313-327, illus.
- (285) ———
1939. The relation of fire to stand composition of longleaf pine forests. Ecology 20: 287-304, illus.
- (286) ——— and Barnette, R. M.
1934. Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Fla. Agr. Expt. Sta. Bul. 265, 39 pp., illus.
- (287) ———
1936. Field characteristics and partial chemical analyses of the humus layer of longleaf pine forest soils. Fla. Agr. Expt. Sta. Bul. 302, 27 pp., illus.
- (288) ——— and Tissot, A. N.
1936. Some changes in the soil fauna associated with forest fires in the longleaf pine region. Ecology 17: 659-666, illus.
- (289) Hine, W. R.
1938. Some observations on planting private forest land. South. Lumberman 157 (1985): 150-153, illus.
- (290) Hine, W. R. B.
1925. Hogs, fire, and disease versus longleaf pine. South. Lumberman 119 (1544): 45-46, illus.
- (291) Hodges, C. S.
1926. Interesting comments on dry facing. Naval Stores Rev. 36 (15): 16.
- (292) Holland, J. H.
1926. Four major causes given for dry-facing in pines. Naval Stores Rev. 36 (17): 6.
- (293) Holmes, J. S., and Foster, J. H.
1908. Condition of cut-over longleaf pine in Mississippi. U. S. Forest Serv. Cir. 149, 8 pp.

- (294) ————
1908. Preliminary report on the condition of cut-over lands in the longleaf pine region of Mississippi. 8 pp. [n. p.] (U. S. Dept. Agr., Forest Serv., in cooperation with Miss. Geol. Survey.)
- (295) Hopkins, A. D.
1903. Some of the principal insect enemies of coniferous forests in the United States. U. S. Dept. Agr. Yearbook 1902: 265-282, illus.
- (296) ————
1904. Catalogue of exhibits of insect enemies of forests and forest products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. U. S. Dept. Agr., Div. Ent. Bul. (n. s.) 48, 56 pp.
- (297) ————
1909. Insect depredations in North American forests and practical methods of prevention and control. U. S. Bur. Ent. Bul. 58: 57-101.
- (298) ————
1909. Practical information on the scolytid beetles of North American forests. I. Barkbeetles of the genus *Dendroctonus*. U. S. Bur. Ent. Bul. 83, Pt. 1, 169 pp., illus.
- (299) ————
1910. Insect injuries to the wood of dying and dead trees. U. S. Bur. Ent. Cir. 127, 3 pp.
- (300) ————
1911. The dying of pine in the southern states: cause, extent, and remedy. U. S. Dept. Agr. Farmers' Bul. 476, 15 pp., illus.
- (301) ————
1921. Contributions toward a monograph of the bark-weevils of the genus *Pissodes*. U. S. Bur. Ent. Tech. Series No. 20: 1-68, illus.
- (302) ————
1921. The southern pine beetle: a menace to the pine timber of the Southern States. U. S. Dept. Agr. Farmers' Bul. 1188, 15 pp., illus.
- (303) Hough, F. B.
1878. Report upon forestry. Prepared under the direction of the Commissioner of Agriculture. 650 pp. Washington.
- (304) Howell, P. N.
1932. My experience with fire in longleaf pine. Amer. Forests: 38, 155-157, 184, illus.
- (305) [Hoxie, F. J.]
1915. Dry rot in factory timbers. 107 pp., illus. Boston.
- (306) ———— and Schrenk, Hermann von.
1916. Resin in yellow pine for decay resistance. Engin. News 75: 765-766, illus.
- (307) Hubbard, H. G.
1897. The ambrosia beetles of the United States. U. S. Dept. Agr. Div. Ent. Bul. (n. s.) 7 (Some Miscellaneous Results of the Work of the Division of Entomology), 9-30.
- (308) Huberman, M. A.
1935. Mechanical advances at the Stuart Forest Nursery. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 48, 8 pp., illus. [Processed.]
- (309) ————
1938. Growing nursery stock of southern pines. U. S. Dept. Agr. Leaflet 155, 8 pp., illus.
- (310) ————
1940. Normal growth and development of southern pine seedlings in the nursery. Ecology 21: 323-334, illus.

- (311) ————
1940. Studies in raising southern pine nursery seedlings. *Jour. Forestry* 38: 341-345.
- (312) Humphrey, C. J.
1916. Laboratory tests on the durability of American woods. I. Flask tests on conifers. *Mycologia* 8: 80-92, illus.
- (313) Hunt, G. M., and Garratt, G. A.
1938. Wood preservation. 457 pp., illus. New York.
- (314) Hurt, A. B.
1883. Mississippi: its climate, soil, productions, and agricultural capabilities. U. S. Dept. Agr. Misc. Special Rpt. 3, 89 pp.
- (315) Illick, J. S.
1921. The pines of the South. *Amer. Forestry* 27: 551-559, 574, illus.
- (316) Ineson, F. A.
1937. Volumes on average acres in the principal units of the naval stores region. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 29, 17 pp., illus. [Processed.]
- (317) ————
1938. The use of round turpentine timber—surveys in the several states and conclusions drawn from them. *Gamble's Internatl. Naval Stores Year Book* 1938-39: 135-137, illus.
- (318) ———— and Eldredge, I. F.
1938. Forest resources of northeastern Florida. U. S. Dept. Agr. Misc. Pub. 313, 40 pp., illus.
- (319) Ivy, T. P.
[1923.] The longleaf pine, with prefatory remarks on the political and geological history of North Carolina and the sandhills, including a summary of the flora and fauna. 16 pp., illus. *Southern Pines*, N. C.
- (320) Jemison, G. M.
1939. The measurement of forest fire danger in the eastern United States and its application in fire control. A progress report. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 35, 43 pp., illus. [Processed.]
- (321) Johnson, J. B.
1893. Results of mechanical tests. U. S. Dept. Agr. Forestry Div. Bul. 8 (Timber Physics, Pt. II), pp. 22-31, illus.
- (322) Johnston, H. R.
1944. Control of the Texas leaf-cutting ant with methyl bromide. *Jour. Forestry* 42: 130-132, illus.
- (323) ———— and Eaton, C. B.
1939. White grubs in forest nurseries of the Carolinas. U. S. Bur. Ent. and Plant Quar. E-486, 8 pp., illus. [Processed.]
- (324) Kimball, K. E.
1924. Minimum requirements of commercial forestry practice. *South. Lumberman* 117 (1525): 198, 200.
- (325) Knorr, Philip.
1942. Variations in fire-danger factors on a ranger district in the longleaf pine region. *Jour. Forestry* 40: 689-692.
- (326) Koehler, Arthur.
1917. Guidebook for the identification of woods used for ties and timbers. Washington. (U. S. Forest Serv. Misc. RL-1.) 79 pp., illus.
- (327) ————
1924. The properties and uses of wood. 354 pp., illus. New York.
- (328) ————
1932. The identification of longleaf pine timbers. *South. Lumberman* 145 (1841): 36-37, illus.

- (329) ————
1938. Wood quality—a reflection of growth environment. *Jour. Forestry* 36: 867-869.
- (330) Kotok, E. I.
1933. Protection against fire. In U. S. Forest Service, A national plan for American forestry. U. S. Cong., 73d, 1st sess., S. Doc. 12, pp. 1395-1414. Washington, D. C.
- (331) Kraemer, L.
1927. The dollars and cents value of density. *South. Lumberman* 129 (1681): 164, 170.
- (332) Kuehn, C. C.
1934. Comparative strength properties of slash and longleaf pines. A thesis submitted to the Yale School of Forestry. 47 pp. Louisville, Ky.
- (333) Lamb, Howard.
1937. Rust canker diseases of southern pines. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 72, 7 pp., illus. [Processed.]
- (334) ———— and Sleeth, Bailey.
1940. Distribution and suggested control measures for the southern pine fusiform rust. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 91, 5 pp., illus. [Processed.]
- (335) Larsen, J. A.
1910. Forest and soils of Caldwell Parish, Louisiana. *Forestry Quart.* 8: 462-464.
- (336) Lawson, John.
1714. *Lawson's History of North Carolina*, containing the exact description and natural history of that country, together with the present state thereof and a journal of a thousand miles traveled through several nations of Indians, etc., etc. 259 pp. London. [Reprinted Richmond, Va., 1937.]
- (337) Leffelman, L. J.
1933. Forest and game management in South Carolina with special reference to game birds. *Jour. Forestry* 31: 658-663.
- (338) Lehrbas, M. M., and Eldredge, I. F.
1941. Forest resources of south Georgia. U. S. Dept. Agr. Misc. Pub. 390, 50 pp., illus.
- (339) Lemieux, F. J.
1936. Log rules, taper tables, and volume tables for use in the South. *Jour. Forestry* 34: 970-974.
- (340) Lenhart, D. Y.
1934. Initial root development of longleaf pine. *Jour. Forestry* 32: 459-461.
- (341) Liefeld, T. A.
1937. Naval-stores yields from bark-bars. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 61, 8 pp., illus. [Processed.]
- (342) ————
1938. Naval stores yields from French and American faces chipped on bark-bars. *Gamble's Internatl. Naval Stores Year Book* 1938-39: 130-131, illus.
- (343) ————
1939. How long will a streak yield gum? *Naval Stores Rev.* 48 (50): 10, 14, illus.
- (344) ————
1940. Increased naval stores production from chemically treated streaks. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 97, 6 pp., illus. [Processed.]
- (345) ————
1942. How important is the advance streak? *AT-FA Jour.* 5 (3): 8-9.

- (346) ———— 1942. Relation of naval stores yields to frequency of chipping. *Jour. Agr. Res.* 64: 81-92, illus.
- (347) ———— Chapman, R. A., and Snow, A. G., Jr.
1943. What is new in chemical stimulation? *AT-FA Jour.* 5 (4): 8-9.
- (348) Lindgren, R. M., Scheffer, T. C., and Chapman, A. D.
1932. Recent chemical treatments for the control of sap stain and mold in southern pine and hardwood lumber. *South. Lumberman* 145 (1827): 43-46.
- (349) ———— 1932. Recent tests of chemical treatments for preventing deterioration in stored logs. *South. Lumberman* 145 (1834): 19-21.
- (350) Lloyd, F. E., and Tracy, S. M.
1901. The insular flora of Mississippi and Louisiana. *Torrey Bot. Club Bul.* 28: 61-101, illus.
- (351) Lockwood, J. E.
1921. Wood rosin and turpentine vs. gum rosin and turpentine. In Gamble, T., *Naval Stores; history, production, distribution, and consumption*, pp. 247, 249. Savannah, Ga.
- (352) Lodewick, J. E.
1930. Effect of certain climatic factors on the diameter growth of longleaf pine in western Florida. *Jour. Agr. Res.* 41: 349-363, illus.
- (353) ———— 1931. Some effects of irrigation and fertilization on the size of longleaf pine needles. *U. S. Forest Serv. Forest Worker* 7 (1): 12-13.
- (354) ———— 1933. Some summer-wood percentage relationships in the southern pines. *Jour. Agr. Res.* 46: 543-556, illus.
- (355) Long, E. C.
1888. Notes on some of the forest features of Florida, with items of tree growth in that state. *Amer. Forestry Cong. Proc.* 7: 38-41.
- (356) ———— 1889. Forest fires in the southern pines. *Forest Leaves* 2: 94.
- (357) Louisiana. Division of Forestry.
1937. Southern fire-break plow. *U. S. Forest Serv. Fire Control Notes* [1]: 338, illus.
- (358) Lowe, E. N.
1921. Plants of Mississippi. *Miss. State Geol. Survey Bul.* 17, 292 pp.
- (359) McArthur, W. E.
1926. Three causes assigned for dry facing. *Naval Stores Rev.* 36 (15): 17.
- (360) McAtee, W. L.
1911. Woodpeckers in relation to trees and wood products. *U. S. Biol. Survey Bul.* 39, 99 pp., illus.
- (361) McCaffrey, J. E.
1942. Progress in industrial forestry. *Jour. Forestry* 40: 89-92, illus.
- (362) McDougald, W. E.
1929. The producer of gum spirits turpentine and gum rosins in the South. *Naval Stores Rev.* 39 (30): 16-17.
- (363) McDougall, W. B.
1928. Mycorrhizas from North Carolina and eastern Tennessee. *Amer. Jour. Bot.* 15: 141-148, illus.
- (364) McKee, E. R.
1923. Naval stores production on the Florida National Forest. *Naval Stores Rev.* 33 (6): 16-17.

- (365) ————
1924. The French turpentine system applied to longleaf pine. U. S. Dept. Agr. Cir. 327, 16 pp., illus.
- (366) McKellar, A. D.
1942. Ice damage to slash pine, longleaf pine, and loblolly pine plantations in the Piedmont section of Georgia. Jour. Forestry 40: 794-797.
- (367) McLendon, S. G.
1890. The Georgia pine. Forest Leaves 3: 13-14.
- (368) MacDonald, Alan.
1940. Turpentine—an old southern industry. Naval Stores Rev. 50 (20): 20-21.
- (369) MacKinney, A. L.
1931. Longleaf pines subjected to thirteen years' light burning show retarded growth. U. S. Forest Serv. Forest Worker 7 (5): 10-11.
- (370) ————
1931. Thirteen annual fires in the longleaf pine type. U. S. Forest Serv. Serv. Bul. 15 (37): 2-4. [Processed.]
- (371) ————
1933. Mortality in longleaf pine pole stand after a hard fire. U. S. Forest Serv. Serv. Bul. 17 (22): 3. [Processed.]
- (372) ————
1934. Some effects of three annual fires on growth of longleaf pine. Jour. Forestry 32: 879-881.
- (373) ————
1934. Some factors affecting the bark thickness of second-growth longleaf pine. Jour. Forestry 32: 470-474.
- (374) MacLean, J. D.
1933. Experiments with the Boulton process in the treatment of green southern pine poles. Amer. Wood Preservers' Assoc. Proc. 1933: 343-359, illus.
- (375) MacNaughton, V. B.
1939. Mississippi fire tanks. U. S. Forest Serv. Fire Control Notes 3 (1): 35-36.
- (376) MacNaughton, W. G., and Allen, W. F.
1933. Georgia pine sulphite and ground wood for news print: observations on experimental production. Paper Trade Jour. 97 (2): 36-40, illus.
- (377) Malsberger, H. J.
1937. Radio and forest fire control in Florida. U. S. Forest Serv. Fire Control Notes [1]: 243-248.
- (378) Markwardt, L. J.
1930. Comparative strength properties of woods grown in the United States. U. S. Dept. Agr. Tech. Bul. 158, 39 pp., illus.
- (379) ———— and Wilson, T. R. C.
1935. Strength and related properties of woods grown in the United States. U. S. Dept. Agr. Tech. Bul. 479, 99 pp., illus.
- (380) Martin, D. F.
1926. Puts it up to deep chipping. Naval Stores Rev. 36 (15): 17.
- (381) Masters, M. T.
1904. A general view of the genus *Pinus*. Linn. Soc. London, Jour. Bot. 35: 560-659, illus.
- (382) Mathews, A. C.
1932. The seed development in *Pinus palustris*. Elisha Mitchell Sci. Soc. Jour. 48: 101-118, illus.
- (383) Mattoon, W. R.
1925. Longleaf pine. U. S. Dept. Agr. Dept. Bul. 1061, rev., 67 pp., illus.
- (384) ————
1930. Longleaf pine primer. U. S. Dept. Agr. Farmers' Bul. 1486, rev., 34 pp., illus.

- (385) ———
1935. Some practical considerations of light burning in the South. *Jour. Forestry* 34: 1004-1005.
- (386) ———
1942. Pruning southern pines. U. S. Dept. Agr. Farmers' Bul. 1892, 34 pp.
- (387) Mease, James.
1808. Supplement to the foregoing [Departure of the southern pine timber, a proof of the tendency in nature to a change of products on the same soil. By Richard Peters.] *Phila. Soc. Promo. Agr. Mem.* 1: 41-46.
- (388) Meyer, H. A.
1942. Methods of forest growth determination. *Penn. Agr. Expt. Sta. Bul.* 435, 93 pp., illus.
- (389) Michaux, F. A.
1805. Travels to the westward of the Alleghany Mountains. 350 pp. London.
- (390) ———
1859. The North American sylvia. 5 v., illus. Philadelphia.
- (391) Middleton, William.
1921. Leconte's sawfly, an enemy of young pines. *Jour. Agr. Res.* 20: 741-760, illus.
- (392) ———
1938. A sawfly injurious to young pines. U. S. Dept. Agr. Farmers' Bul. 1259, rev., 6 pp., illus.
- (393) Miller, R. H.
1941. Measuring green southern yellow pine pulpwood by weight or by cord. *Paper Trade Jour.* 113 (3): 31-33, illus.
- (394) Mills, E. B.
1926. Drought, deep chipping and pine beetles cause dry faces. *Naval Stores Rev.* 36 (17): 6.
- (395) Mitchell, H. C.
1943. Regulation of farm woodlands by rule of thumb. *Jour. Forestry* 41: 243-248, illus.
- (396) Mohr, C. T.
1888. The long-leafed pine. *Gard. and Forest* 1: 261-262.
- (397) ———
1897. The timber pines of the southern United States. U. S. Dept. Agr. Div. Forestry Bul. 13, rev., 176 pp., illus.
- (398) ———
1901. Plant life of Alabama. U. S. Dept. Agr. Div. Bot. Contrib. U. S. Nat'l. Herbarium 6, 921 pp.
- (399) Morrell, Fred.
1932. Effects of fire on longleaf pine. U. S. Forest Serv. Serv. Bul. 16 (22): 5-6 [Processed.]
- (400) Morriss, D. J.
1941. Florida's one-man "crew." U. S. Forest Serv. Fire Control Notes 5: 79-80.
- (401) Munson, T. V.
1883. Forests and forest trees of Texas. *Amer. Jour. Forestry* 1: 433-451.
- (402) Muntz, H. H.
1944. Effects of compost and stand density upon longleaf and slash pine nursery stock. *Jour. Forestry* 42: 114-118, illus.
- (403) Myer, J. E.
1922. Ray volumes of the commercial woods of the United States and their significance. *Jour. Forestry* 20: 337-351.
- (404) Nelson, M. L.
1938. Preliminary investigations on dry, cold storage of southern pine seed. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 78, 19 pp. [Processed.]

- (405) ————
1940. Successful storage of southern pine seed for seven years. *Jour. Forestry* 38: 443-444.
- (406) ————
1941. Polyembryony in seeds of southern pines. *Jour. Forestry* 39: 959-960.
- (407) Ness, Helge.
1922. Cultivation and care of trees on the farm in Texas. *Tex. Agr. Expt. Sta. Bul.* 293, 76 pp., illus.
- (408) ————
1927. The distribution limits of the longleaf pine and their possible extension. *Jour. Forestry* 25: 852-857.
- (409) Newlin, J. A., and Wilson, T. R. C.
1917. Mechanical properties of woods grown in the United States. *U. S. Dept. Agr. Bul.* 556, 47 pp., illus.
- (410) ————
1919. The relation of the shrinkage and strength properties of wood to its specific gravity. *U. S. Dept. Agr. Bul.* 676, 35 pp., illus.
- (411) Oettmeier, W. M.
1937. One-way versus two-way radio communication. *U. S. Forest Serv. Fire Control Notes* 1: 365-366.
- (412) Olsen, C. F.
1941. An analysis of the Honey fire. *U. S. Forest Serv. Fire Control Notes* 5: 161-178.
- (413) Osborne, J. G.
1933. Osceola Forest records show cost of thinning longleaf pine. *U. S. Forest Serv. Forest Worker* 9 (1): 9-10.
- (414) ————
1938. Effects of burned faces on later turpentine. *Forestry News Digest*, May, 1938, p. 23.
- (415) ———— and Harper, V. L.
1937. The effect of seedbed preparation on first-year establishment of longleaf and slash pine. *Jour. Forestry* 35: 63-68.
- (416) Paddock, W. R.
1940. Dogs as a fire-prevention tool in the South. *U. S. Forest Serv. Fire Control Notes* 4: 23-25.
- (417) Palkin, Samuel.
1932. The fractionation of American gum spirits of turpentine and evaluation of its pinene content by optical means. *U. S. Dept. Agr. Tech. Bul.* 276, 14 pp., illus.
- (418) ———— Chadwick, T. C., and Matlack, M. B.
1937. Composition and fractionation of American steam-distilled wood turpentine. *U. S. Dept. Agr. Tech. Bul.* 596, 30 pp.
- (419) Palmer, R. C.
1921. Wood rosin, steam distilled turpentine and pine oil, their characteristics and uses. *In* Gamble, T., *Naval Stores; history, production, distribution, and consumption*, pp. 259-263. Savannah, Ga.
- (420) Paul, B. H.
1926. Influence of fires on growth of pine. *South. Lumberman* 122 (1582 [i.e., 1583]): 41.
- (421) ————
1927. Producing dense southern pine timber in second-growth forests. *South. Lumberman* 128 (1668): 46-47, illus.

- (422) ————
1929. Relation of growth factors to wood quality, growing space—longleaf pine. South. Lumberman 137 (1768): 53-54, illus.
- (423) ————
1930. Cupping of plain sawed lumber and checking of timbers, based on studies of slow, medium, and rapid growth longleaf pine. South. Lumberman 140 (1786): 47-48, illus.
- (424) ————
1930. Heartwood in second-growth southern pines. Naval Stores Rev. 40 (29): 28, illus.
- (425) ————
1930. The application of silviculture in controlling the specific gravity of wood. U. S. Dept. Agr. Tech. Bul. 168, 20 pp., illus.
- (426) ————
1931. The relation of growth factors to wood quality—thinnings in southern pine. South. Lumberman 143 (1804): 80-81.
- (427) ————
1938. Knots in second-growth pine and the desirability of pruning. U. S. Dept. Agr. Misc. Pub. 307, 36 pp., illus.
- (428) ————
1938. When to prune southern pines. South. Lumberman 157 (1985): 143-145, illus.
- (429) ————
1939. Variation in specific gravity of the springwood and summerwood of four species of southern pines. Jour. Forestry 37: 478-482, illus.
- (430) ————
1941. Thinning and quality; sudden acceleration of diameter growth in vertical and leaning longleaf pine trees in relation to quality of lumber. South. Lumberman 163 (2057): 203-206, illus.
- (431) ———— and Marts, R. O.
1931. Controlling the proportion of summerwood in longleaf pine. Jour. Forestry 29: 784-796, illus.
- (432) Pease, T. E.
1937. Dull chipping tools cause fifteen percent loss in gum yield. U. S. Forest Serv. South. Forest Exp. Sta. Occas. Paper 60, 3 pp., illus. [Processed.]
- (433) Penfound, W. T., and Watkins, A. G.
1937. Phytosociological studies in the pinelands of southeastern Louisiana. Amer. Midland Nat. 18: 661-682, illus.
- (434) Pessin, L. J.
1928. Mycorrhiza of southern pines. Ecology 9: 28-33, illus.
- (435) ————
1930. Timber and cattle can be raised together on southern cutover land. U. S. Dept. Agr. Yearbook 1930: 512-514, illus.
- (436) ————
1933. Forest associations in the uplands of the lower Gulf Coastal Plain (longleaf pine belt). Ecology 14: 1-14, illus.
- (437) ————
1933. How old is a longleaf pine? U. S. Forest Serv. Forest Worker 9 (1): 12-13.
- (438) ————
1934. Annual ring formation in *Pinus palustris* seedlings. Amer. Jour. Bot. 21: 599-603, illus.
- (439) ————
1934. Effect of flower production on rate of growth of vegetative shoots of longleaf pine. Science 80: 363-364.

- (440) ————
1935. A new use for longleaf pine needles. U. S. Forest Serv. Serv. Bul. 19 (14): 3-4. [Processed.]
- (441) ————
1935. Root habits of longleaf pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 43, 7 pp., illus. [Processed.]
- (442) ————
1936. Unusual longleaf pine seedlings. Jour. Forestry 34: 817-818, illus.
- (443) ————
1937. The effect of nutrient deficiency on the growth of longleaf pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 65, 7 pp., illus. [Processed.]
- (444) ————
1938. Effect of soil moisture on the rate of growth of longleaf and slash pine seedlings. Plant Physiol. 13: 179-189.
- (445) ————
1938. The effect of vegetation on the growth of longleaf pine seedlings. Ecol. Monog. 8: 115-149, illus.
- (446) ————
1939. Density of stocking and character of ground cover as factors in longleaf pine reproduction. Jour. Forestry 37: 255-258, illus.
- (447) ————
1939. Ground cover and pine seedlings. Effect of treatment on growth of longleaf. Naval Stores Rev. 48 (44): 6.
- (448) ————
1939. Root habits of longleaf pine and associated species. Ecology 20: 47-57, illus.
- (449) ————
1941. Recommendations for killing scrub oaks in the longleaf pine type. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes, May 1941, p. 2. [Processed.]
- (450) ————
1942. Recommendations for killing scrub oaks and other undesirable trees. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 102, 5 pp., illus. [Processed.]
- (451) ————
1942. Stimulating the early growth of longleaf pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 44: 2. [Processed.]
- (452) ————
1944. Stimulating the early height growth of longleaf pine seedlings. Jour. Forestry 42: 95-98.
- (453) ———— and Chapman, R. A.
1944. The effect of living grass on the growth of longleaf pine seedlings in pots. Ecology 25: 85-90.
- (454) ———— and Shepard, A. L.
1941. A tool to make holes for poison injection. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 38: 1. [Processed.]
- (455) Peters, J. G.
1916. Forest conservation for states in the southern pine region. U. S. Dept. Agr. Bul. 364, 14 pp.
- (456) Philips, V. G.
1929. How to get larger returns from turpentine and carry them over longer periods. Naval Stores Rev. 38 (47): 14-15, 27, 29.

- (457) ————
1929. Turpentine farm management. Pine Inst. of Amer. Pine Tree Chem. Indus. Year Book 1929: 38-41.
- (458) Pillow, M. Y.
1931. Compression wood records hurricane. Jour. Forestry 29: 575-578, illus.
- (459) ———— and Luxford, R. F.
1937. Structure, occurrence, and properties of compression wood. U. S. Dept. Agr. Tech. Bul. 546, 32 pp., illus.
- (460) Pinchot, Gifford.
1899. The relation of forests and forest fires. Natl. Geog. Mag. 10: 393-403, illus.
- (461) ————
1903. A new method of turpentine orcharding. U. S. Dept. Agr. Bur. Forestry Cir. 24, 8 pp., illus.
- (462) ———— and Ashe, W. W.
1897. Timber trees and forests of North Carolina. N. C. Geol. Survey Bul. 6, 227 pp., illus.
- (463) Porcher, F. P.
1869. Resources of the southern fields and forests, medical, economical, and agricultural. Ed. 2, 733 pp. Charleston, S. C.
- (464) Reed, F. W.
1905. A working plan for forest lands in central Alabama. U. S. Forest Serv. Bul. 68, 71 pp., illus.
- (465) Reynolds, R. V., and Pierson, A. H.
1939. Forest products statistics of the southern states. U. S. Dept. Agr. Statis. Bul. 69, 106 pp., illus.
- (466) Rhodes, J. G.
1926. Three causes of dry facing. Naval Stores Rev. 36 (15): 17.
- (467) Rietz, R. C.
1939. Effect of five kiln temperatures on the germinative capacity of longleaf pine seed. Jour. Forestry 37: 960-963, illus.
- (468) ————
1941. Kiln design and development of schedules for extracting seed from cones. U. S. Dept. Agr. Tech. Bul. 773, 70 pp., illus.
- (469) Righter, F. I.
1939. Early flower production among the pines. Jour. Forestry 37: 935-938, illus.
- (470) Roberts, E. G.
1936. Germination and survival of longleaf pine. Jour. Forestry 34: 884-885.
- (471) Rogers, J. E.
1931. The tree book, a popular guide to a knowledge of the trees of North America and to their uses and cultivation. 589 pp., illus. New York.
- (472) Ross, C. R.
1942. A forty-year-old planted longleaf stand. Jour. Forestry 40: 581-584, illus.
- (473) Roth, Filibert.
1897. Additional notes on longleaf pine. In Mohr, Charles. Timber pines of the southern United States. U. S. Dept. Agr. Div. Forestry Bul. 13, rev., pp. 74-75.
- (474) ————
1897. Notes on the structure of the wood of five southern pines. In Mohr, Charles. Timber pines of the southern United States. U. S. Dept. Agr. Div. Forestry Bul. 13, rev., pp. 143-153.
- (475) Rothkugel, Max.
1907. Forest management in southern pines. Forestry Quart. 5: 1-10.

- (476) [Ruffin, Edmund.]
1858. Notes on the pine trees of lower Virginia and North Carolina. Russell's Mag. 4: 34-42, 139-151.
- (477) Rumbold, C. T.
1931. Two blue-staining fungi associated with bark-beetle infestation of pines. Jour. Agr. Res. 43: 847-873, illus.
- (478) St. George, R. A.
1924. Southern pine beetle and other insect enemies of southern forests. Lumber Trade Jour. 86 (9): 37-38.
- (479) —————
1925. The recent death of large quantities of southern pine. Amer. Lumberman, No. 2607, 3 pp., 50-51, illus.
- (480) ————— and Beal, J. A.
1929. The southern pine beetles, a serious enemy of pines in the South. U. S. Dept. Agr. Farmers' Bul. 1586, 18 pp., illus.
- (481) Sargent, C. S.
1884. Report on the forests of North America (exclusive of Mexico). 612 pp. Washington, D. C. (U. S. Dept. Int. Census Off. [10th Census. Rpt. v. 9.])
- (482) Scheffer, T., and Lindgren, R. M.
1940. Stains of sapwood and sapwood products and their control. U. S. Dept. Agr. Tech. Bul. 714, 124 pp., illus.
- (483) Schorger, A. W.
1916. The conifer leaf oil industry. Amer. Lumberman No. 2137, pp. 28-29.
- (484) —————
1917. Mannan content of the gymnosperms. Jour. Forestry 15: 197-202, illus.
- (485) —————
1917. The chemistry of wood. Jour. Indus. and Engin. Chem. 9: 556-566.
- (486) —————
1926. The chemistry of cellulose and wood. 596 pp., illus. New York.
- (487) ————— and Betts, H. S.
1915. The naval stores industry. U. S. Dept. Agr. Bul. 229, 58 pp., illus.
- (488) Schumacher, F. X., and Day, B. B.
1939. The influence of precipitation upon the width of annual rings of certain timber trees. Ecol. Monog. 9: 387-429, illus.
- (489) Schwarz, G. F.
1907. The longleaf pine in virgin forest. 135 pp., illus. New York.
- (490) Sebring, H. M.
1931. Forest management for naval stores. Ga. Forest Service Bul. 13 [i.e., 14], 21 pp., illus.
- (491) ————— and Thurmond, Jack.
1931. Planting longleaf and slash pines. Ga. Forest Service Bul. 16, 26 pp., illus.
- (492) Sellards, E. H., Harper, R. M., Mooney, C. N., Latimer, W. J., Gunter, Herman, and Gunter, Emil.
1915. Natural resources survey of an area in central Florida. Fla. Geol. Survey Ann. Rept. 7: 117-188, illus.
- (493) Sellars, J. D.
1926. Deep broad chipping the cause. Naval Stores Rev. 36 (15): 16.
- (494) Shaw, G. R.
1914. The genus *Pinus*. Arnold Arboretum Pub. 5, 96 pp., illus.
- (495) Shepard, A. L.
1940. Another use for pine needles. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes, July 1940, p. 3. [Processed.]

- (496) Shepard, H. B., and Bailey, I. W.
1914. Some observations on the variation in length of coniferous fibers. Soc. Amer. Foresters Proc. 9: 522-527.
- (497) Sherrard, T. H.
1903. A working plan for forest lands in Hampton and Beaufort Counties, South Carolina. U. S. Bur. Forestry Bul. 43, 54 pp., illus.
- (498) Siggers, P. V.
1932. The brown-spot needle blight of longleaf pine seedlings. Jour. Forestry 30: 579-593.
- (499) —————
1934. Observations on the influence of fire on the brown-spot needle blight of longleaf pine seedlings. Jour. Forestry 32: 556-562, illus.
- (500) —————
1939. *Scirrhia acicola* (Dearn.), n. comb., the perfect stage of the fungus causing the brown-spot needle blight of pines. Phytopathology 29: 1076-1077.
- (501) —————
1944. The brown spot needle blight of pine seedlings. U. S. Dept. Agr. Tech. Bul. 870, 36 pp., illus.
- (502) Siggins, H. W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128, illus.
- (503) Simerly, N. G. T.
1936. Controlled burning in longleaf pine second growth timber. Jour. Forestry 34: 671-673.
- (504) Small, J. K.
1923. Land of the question mark. N. Y. Bot. Gard. Jour. 24: 1-23, 25-43, 62-70, illus.
- (505) Smith, B. F.
1932. Forestry at Elizabeth, Louisiana. Jour. Forestry 30: 312-316.
- (506) Smith, E. B.
1921. Destructive distillation of wood as applied to the naval stores industry. In Gamble, T., Naval Stores; history, production, distribution, and consumption, pp. 253-257, illus. Savannah, Ga.
- (507) Smith, M. R.
1939. The Texas leaf-cutting ant (*Atta texana* Buckley) and its control in the Kisatchie National Forest of Louisiana. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 84, 11 pp., illus. [Processed.]
- (508) Snow, A. G., Jr.
1944. How to obtain increased yield of gum from virgin cupping. Naval Stores Rev. 53 (46): 8, 10, illus.
- (509) —————
1944. Iron corrosion by sulphuric acid stopped with arsenic. Naval Stores Rev. 54 (18): 8.
- (510) —————
1945. The use of chemical stimulants to increase gum yields in slash and longleaf pines. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 106, 36 pp. [Processed.]
- (511) Snow, E. A.
1940. The Herbert fire plow. U. S. Forest Serv. Fire Control Notes 4: 43-45.
- (512) Snyder, T. E.
1915. Insects injurious to forests and forest products. II. Biology of the termites of eastern United States, with preventive and remedial measures. U. S. Bur. Ent. Bul. 94: 13-95, illus.

- (513) _____
1924. Tests of methods of protecting woods against termites or white ants. U. S. Dept. Agr. Bul. 1231, 16 pp., illus.
- (514) _____
1927. Defects in timber caused by insects. U. S. Dept. Agr. Dept. Bul. 1490, 46 pp., illus.
- (515) _____
1928. Insect damage to yellow and white pine timbers in the roof of the White House. Wash. Acad. Sci. Jour. 18: 381-382.
- (516) _____
1932. Wood as food of insects. South. Lumberman 145 (1828): 27.
- (517) _____
1933. Bark beetles in relation to selective cutting. South. Pine Assoc. South. Pine Forestry Notes 24, 1 p.
- (518) _____
1936. Injury to buildings by termites. U. S. Dept. Agr. Leaflet 101, 8 pp., illus.
- (519) _____
1937. Damage to young pines by a leaf-cutting ant, *Atta texana* Buckley, in Louisiana. La. Conserv. Rev. 6 (1): 14-17, illus.
- (520) _____
1940. The browning of the needles of young yellow pine trees in the Gulf States by a leaf-feeding beetle (*Colaspis pini* Barber). South. Lumberman 160 (2020): 46, illus.
- (521) Society of American Foresters. Committee on Forest Types.
1940. Forest cover types of the eastern United States; report of Committee on Forest Types. 3d ed., 39 pp. Washington.
- (522) Society of American Foresters, Southeastern Section.
1934. Standard turpentine practice. Jour. Forestry 32: 344-346.
- (523) Southern Pine Association.
1939. Standard specifications for southern pine lumber conforming to American lumber standards. 116 pp., illus. New Orleans, La.
- (524) Sparhawk, W. N.
1925. The use of liability ratings in planning forest fire protection. Jour. Agr. Res. 30: 693-762, illus.
- (525) Spillers, A. R.
1938. Forest resources of central and south Florida. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 38, 30 pp., illus. [Processed.]
- (526) _____
1938. Forest resources of northwest Florida. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 33, 33 pp., illus. [Processed.]
- (527) _____
1938. Forest resources of southwest Alabama. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 35, 35 pp., illus. [Processed.]
- (528) _____
1939. Forest resources of central Georgia. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 41, 29 pp., illus. [Processed.]
- (529) _____ and I. F. Eldredge
1943. Georgia forest resources and industries. U. S. Dept. Agr. Misc. Pub. 501, 70 pp., illus.
- (530) Starker, T. J.
1934. Fire resistance in the forest. Jour. Forestry 32: 462-467.
- (531) Steer, H. B.
1938. Stumpage prices of privately owned timber in the United States. U. S. Dept. Agr. Tech. Bul. 626, 163 pp., illus.

- (532) Stephenson, G. K.
1936. An application of fire statistics to fire control. *Jour. Forestry* 34: 996-1002, illus.
- (533) Stoddard, H. L.
1931. The bob white quail; its habits, preservation and increase. 559 pp., illus. New York.
- (534) —————
1935. Use of controlled fire in southeastern upland game management. *Jour. Forestry* 33: 346-351.
- (535) —————
1935. Use of fire on southeastern game lands. 19 pp. Coop. Quail Study Assoc. Sherwood Plantation, Thomasville, Ga.
- (536) —————
1937. Use of mechanical brush-cutters in wildlife management. *Jour. Wildlife Mangt.* 1: 42-44, illus.
- (537) —————
1939. The use of controlled fire in southeastern game management. Coop. Quail Study Assoc. 21 pp. Sherwood Plantation, Thomasville, Ga.
- (538) Stone, E. L., Jr.
1940. Frost rings in longleaf pine. *Science* 92: 478.
- (539) —————
1942. Effect of fire on radial growth of longleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes, Jan. 1942, p. 3. [Processed.]
- (540) —————
1944. Effect of fire on taper of longleaf pine. *Jour. Forestry* 42: 607.
- (541) ————— and Smith, L. F.
1941. Hail damage in second-growth longleaf pine. *Jour. Forestry* 39: 1033-1035, illus.
- (542) Sudworth, G. B.
1927. Check list of the forest trees of the United States, their names and ranges. U. S. Dept. Agr. Misc. Cir. 92, 295 pp.
- (543) Surface, H. E., and Cooper, R. E.
1914. Suitability of longleaf pine for paper pulp. U. S. Dept. Agr. Bul. 72, 26 pp.
- (544) Sutherland, M.
1934. A microscopical study of the structure of the leaves of the genus *Pinus*. New Zeal. Inst. Trans. and Proc. 63: 517-568, illus.
- (545) Sylvester, W. A.
1938. A comparison of two methods of yield table construction. With a prefatory note by H. H. Chapman. *Jour. Forestry* 36: 681-684. [Comments by Francis X. Schumacher, pp. 684-686.]
- (546) Taylor, A. M.
1927. Some ecological habitats in the longleaf pine flats of Louisiana. *Torrey Bot. Club Bul.* 54: 155-172.
- (547) Teesdale, C. H.
1914. Relative resistance of various conifers to injection with creosote. U. S. Dept. Agr. Bul. 101, 43 pp., illus.
- (548) ————— and MacLean, J. D.
1918. Tests of the absorption and penetration of coal tar and creosote in longleaf pine. U. S. Dept. Agr. Bul. 607, 43 pp., illus.
- (549) Teesdale, L. V.
1927. The kiln drying of longleaf pine. *South. Lumberman* 129 (1681): 165-170, illus.

- (550) ————
1930. The kiln drying of southern yellow pine lumber. U. S. Dept. Agr. Tech. Bul. 165, 67 pp., illus.
- (551) Terry, E. I.
1941. The future of forestry and grazing in the southern pine belt. Sci. Monthly 52: 245-256, illus.
- (552) Tiemann, H. D.
1906. Effect of moisture upon the strength and stiffness of wood. U. S. Forest Serv. Bul. 70, 144 pp., illus.
- (553) ————
1907. The strength of wood as influenced by moisture. U. S. Forest Serv. Cir. 108, 42 pp., illus.
- (554) ————
1910. The physical structure of wood in relation to its penetrability by preservative fluids. Amer. Ry. Engin. and Maintenance-of-Way Assoc. Bul. 120: 359-375, illus.
- (555) Toumey, J. W.
1926. Collection of longleaf pine seed in Texas. Jour. Forestry 24: 728-729.
- (556) Turner, E. R.
1926. More points on causes of dry faces in trees worked for turpentine. Naval Stores Rev. 36 (20): 10.
- (557) U. S. Bureau of Agricultural Chemistry and Engineering.
1942. Production of naval stores. By Naval Stores Division. U. S. Dept. Agr. Misc. Pub. 476, 10 pp.
- (558) U. S. Bureau of the Census.
1925. Forest products: 1923. Turpentine and rosin. 11 pp. Washington.
- (559) U. S. Entomological Commission.
1890. Fifth report of the United States Entomological Commission, being a revised and enlarged edition of Bulletin No. 7, on insects injurious to forest and shade trees. By Alpheus S. Packard. 957 pp. Washington.
- (560) U. S. Forest Service.
1928. Growing pine timber for profit in the South; some examples, estimates, and opinions by lumbermen and others. U. S. Dept. Agr. Misc. Pub. 24, 13 pp.
- (561) ————
1929. Volume, yield, and stand tables for second-growth southern pines. U. S. Dept. Agr. Misc. Pub. 50, 202 pp., illus.
- (562) ————
1932. Federal policy relating to controlled burning in longleaf pine region. U. S. Dept. Agr., Forest Worker 8 (4): 7-9.
- (563) ————
1933. A national plan for American forestry. U. S. 73d Cong., 1st sess. S. Doc. 12. 2 v.
- (564) ———— Div. of State and Private Forestry.
1942. Volume tables, converting factors, and other information applicable to commercial timber in the South. Ed. 4, 45 pp. [Processed.]
- (565) ———— Forest Products Laboratory.
1935. Wood handbook; basic information on wood as a material of construction with data for its use in design and specifications. 326 pp. Washington, D. C.
- (566) ———— Southern Forest Experiment Station.
1933. Stand improvement measures for southern forests. U. S. Emergency Conserv. Work Forestry Pub. 3, 37 pp., illus.

- (567) ————
1936. Longleaf pine stumpwood supply in four southeastern survey units. U. S. Forest Serv. South. Forest Expt. Sta. Forest Survey Release 20, 7 pp., illus. 1936. [Processed.]
- (568) ————
1937. Effect on gum yield of defoliation by fire. South. Pine Assoc. Forestry Notes 18, 1 p.
- (569) ———— U. S. Bureau of Entomology and Plant Quarantine, and U. S. Bureau of Plant Industry.
1935. A naval stores handbook dealing with the production of pine gum or oleoresin. U. S. Dept. Agr. Misc. Pub. 209, 201 pp., illus.
- (570) Uphof, J. C. T.
1938. Die Walder der langnadeligen kiefern Floridas. Deut. Dendrol. Gesell. Mitt. 51: 1-8, illus.
- (571) Vance, L. J.
1895. The future of the longleaf pine belt. Gard. and Forest 8: 278-279.
- (572) Vasey, George.
1883. The coniferae of the United States and Canada. Amer. Jour. Forestry 1: 163-179.
- (573) Veitch, F. P., and Grotlisch, V. E.
1921. Turpentine, its sources, properties, uses, transportation, and marketing. U. S. Dept. Agr. Bul. 898, rev., 53 pp., illus.
- (574) Verrall, A. F.
1934. The resistance of saplings and certain seedlings of *Pinus palustris* to *Septoria acicola*. Phytopathology 24: 1262-1264.
- (575) ————
1936. The dissemination of *Septoria acicola* and the effect of grass fires on it in pine needles. Phytopathology 26: 1021-1024.
- (576) Vilmorin, M. L. de
1897. *Pinus palustris* in France. Gard. and Forest 10: 112-113, 115, illus.
- (577) Vining, L. D.
1928. Damage resulting from recent Florida hurricane to second growth turpentine timber. Naval Stores Rev. 38 (37): 14, illus.
- (578) Wackerman, A. E.
1937. Thinning specifications for southern pine. South. Pine Assoc. South. Pine Forestry Note 33, 1 p.
- (579) Wahlenberg, W. G.
1928. Studies in the production of longleaf pine seeds. Naval Stores Rev. 38 (7): 28.
- (580) ————
1934. Dense stands of reproduction and stunted individual seedlings of longleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 39, 16 pp., illus. [Processed.]
- (581) ————
1935. Effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. Jour. Forestry 33: 331-337.
- (582) ————
1935. Fire in longleaf pine forests. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 40, 4 pp. [Processed.]
- (583) ————
1936. Effect of annual burning on thickness of bark in second growth longleaf pine stands at McNeill, Miss. Jour. Forestry 34: 79-81.

- (584) _____
1937. Pasturing woodland in relation to southern forestry. *Jour. Forestry* 35: 550-556.
- (585) _____
1941. Methods of forecasting timber growth in irregular stands. U. S. Dept. Agr. Tech. Bul. 796, 56 pp., illus.
- (586) _____ and Gemmer, E. W.
1936. Southern forest ranges. In U. S. Forest Service. *The Western Range*. U. S. Cong., 74th, 2d sess., S. Doc. 199: pp. 567-580, illus.
- (587) _____ Greene, S. W., and Reed, H. R.
1939. Effects of fire and cattle grazing on longleaf pine lands as studied at McNeill, Mississippi. U. S. Dept. Agr. Tech. Bul. 683, 52 pp., illus.
- (588) Wakeley, P. C.
1928. Longleaf pine reproduction in the South. *Naval Stores Rev.* 38 (2): 10-11.
- (589) _____
1928. Testing the quality of pine seed. *South. Lumberman* 133 (1734): 222, illus.
- (590) _____
1928. What price natural regeneration? U. S. Forest Serv. *Forest Worker* 4 (3): 8.
- (591) _____
1930. Seed yield data for southern pines. *Jour. Forestry* 28: 391-394.
- (592) _____
1931. Some observations on southern pine seed. *Jour. Forestry* 29: 1150-1164, illus.
- (593) _____
1931. Successful storage of longleaf pine seed. U. S. Forest Serv. *Forest Worker* 7 (1): 10.
- (594) _____
1935. Artificial reforestation in the southern pine region. U. S. Dept. Agr. Tech. Bul. 492, 115 pp., illus.
- (595) _____
1938. Harvesting and selling seed of southern pines. U. S. Dept. Agr. Leaflet 156, 8 pp., illus.
- (596) _____
1939. Storing southern pine seed on a commercial scale. *South. Lumberman* 159 (2009): 114.
- (597) Wallace, W. G.
1940. Direct seeding of longleaf pine indicated as a practical method of reforestation. *Jour. Forestry* 38: 289.
- (598) Watson, Leroy, Jr.
1940. Controlled burning and the management of longleaf pine. *Jour. Forestry* 38: 44-47.
- (599) Webb, J. L.
1909. Some insects injurious to forests. IV. The southern pine sawyer. *Bur. Ent. Bul.* 58: 41-56.
- (600) _____
1911. Injuries to forests and forest products by roundheaded borers. U. S. Dept. Agr. Yearbook 1910: 341-358, illus.
- (601) Webster, C. B.
1930. Comments on "brown-spot" disease of pine needles in Texas. *Jour. Forestry* 28: 767-769.

- (602) Weiss, H. F.
1912. Structure of commercial woods in relation to the injection of preservatives. Amer. Wood Preservers' Assoc. Proc. 8: 159-187, illus.
- (603) Wells, B. W.
1928. Plant communities of the coastal plain of North Carolina and their successional relations. Ecology 9: 230-242.
- (604) ——— and Shunk, I. V.
1931. The vegetation and habitat factors of the coarser sands of the North Carolina coastal plain: an ecological study. Ecol. Monog. 1: 465-520.
- (605) Wilde, S. A.
1941. Forest soils; origin, properties, relation to vegetation, and silvicultural management. 384 pp., illus. Madison, Wis. [Processed.]
- (606) Wildermuth, Robert, Elwell, J. A., Williams, B. H., Gray, A. L., Kerr, J. A., and Edwards, M. J.
1928. Soil survey, Harrison County, Mississippi. U. S. Bur. Chem. and Soils. Soil Survey Rpt. Ser. 1924, No. 7, 48 pp., maps.
- (607) Wilson, T. R. C.
1932. Strength-moisture relations for wood. U. S. Dept. Agr. Tech. Bul. 282, 88 pp., illus.
- (608) ———
1934. Guide to the grading of structural timbers and the determination of working stresses. U. S. Dept. Agr. Misc. Pub. 185, 27 pp.
- (609) Winters, R. K., Ward, G. B., and Eldredge, I. F.
1943. Louisiana forest resources and industries. U. S. Dept. Agr. Misc. Pub. 519, 44 pp., illus.
- (610) Wolf, F. A., and Barbour, W. J.
1941. Brown-spot needle disease of pines. Phytopathology 31: 61-74.
- (611) Woods, J. B.
1925. Timber growing in the South. South. Lumberman 121 (1577): 157, 159.
- (612) Woodward, K. W.
1917. Tree growth and climate in the United States. Jour. Forestry 15: 521-531.
- (613) Woolsey, T. S., Jr.
1926. Review of "Factors determining natural reproduction of longleaf pine on cut-over lands in La Salle Parish, Louisiana." By Herman H. Chapman. Yale University Bul. 16. Jour. Forestry 24: 288-289.
- (614) Worthington, R. E.
1939. Costs of tractor logging in southern pine. U. S. Dept. Agr. Tech. Bul. 700, 64 pp., illus.
- (615) ——— and Yencso, Joseph.
1936. An investigation in pulpwood production from round and turpentine longleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 58, 42 pp., illus. [Processed.]
- (616) Wyman, Lenthall.
1922. Results from sample plots in southern pine experiments. Jour. Forestry 20: 780-787.
- (617) ———
1924. How deep should I chip my timber? South. Lumber Jour. 50 (24): 20.
- (618) ———
1924. How fast should a face be raised in chipping timber? South. Lumber Jour. 50 (20): 17-18, illus.
- (619) ———
1926. Preliminary naval stores yield tables [4] pp., illus. In Naval Stores Rev., v. 36, No. 33.

- (620) ———— 1927. Turpentine pine chipping to get highest yields. U. S. Dept. Agr. Yearbook 1926: 738-741, illus.
- (621) ———— 1928. Conservative turpentineing the key to forest prosperity. South. Lumberman 133 (1734): 221-222, illus.
- (622) ———— 1928. Gum yields of pines increase fast with diameter increase. U. S. Dept. Agr. Yearbook 1927: 355-356.
- (623) ———— 1928. Naval-stores yield much affected by methods of chipping. U. S. Dept. Agr. Yearbook 1927: 473-475.
- (624) ———— 1929. Factors which influence yield of gum and other forest products. Pine Inst. of Amer. Pine Tree Chem. Indus. Yearbook 1929: 31-33.
- (625) ———— 1929. Florida naval stores. Fla. Dept. Agr. Bul. (n. s.) 25, 42 pp., illus.
- (626) ———— 1929. French faces made quickly with new turpentineing tool. U. S. Forest Serv. Forest Worker 5 (5): 13.
- (627) ———— 1929. Narrow chipping in end shown to increase the yield of gum. Naval Stores Rev. 39 (38): 25.
- (628) ———— 1930. Higher returns from turpentine forests. Naval Stores Rev. 40 (12): 15-16.
- (629) ———— 1932. Evaporation of volatile material from scrape. Naval Stores Rev. 41 (45): 12.
- (630) ———— 1932. Experiments in naval stores practice. U. S. Dept. Agr. Tech. Bul. 298, 60 pp., illus.
- (631) ———— 1932. The effect of jump streak on scrape formation. Naval Stores Rev. 41 (43): 18.
- (632) ———— 1932. The effect of raising tins on scrape formation. Naval Stores Rev. 41 (44): 18.
- (633) ———— 1932. The proportion of scrape formed by slash and longleaf pines. Naval Stores Rev. 41 (41): 16; (42): 18.
- (634) ———— 1933. Management of farm woodlands for naval stores production. Jour Forestry 31: 849-852.
- (635) Zeller, S. M.
1917. Physical properties of wood in relation to decay induced by *Lenzites saepiaria* Fries. Mo. Bot. Gard. Ann. 4: 93-164, illus.
- (636) Ziegler, E. A., and Bond, W. E.
1932. Financial aspects of growing pine in the South. Jour. Forestry 30: 284-297. (Comments, pp. 297-300.)
- (637) ———— Spillers, A. R., and Coulter, C. H.
1931. Financial aspects of growing southern pine, Washington County, Fla. Fla. Forest Service Bul. 7, 77 pp., illus.



PLATE 1.—A. A typical virgin longleaf turpentine stand composed almost entirely of merchantable trees, St. Tammany Parish, La. B. A dense stand of second-growth longleaf pine. F-218247, 428691

(Numbers following captions refer to U. S. Forest Service photographic files.)



PLATE 2.—Devastation, actual and potential, resulting from clear cutting. *A*. The trees are poor and insufficient to reseed the land. *B*. Natural regeneration can be expected from this thinly stocked stand only after proper seed-bed preparation and effective protection from hogs. F.409237, 409240



PLATE 3.—On young longleaf pine trees the gray bark is deeply furrowed; on older trees the furrows become shallower and the bark is orange-brown. As diameter growth declines with age, the bark becomes lighter and the exterior scales appear more numerous and papery. *A.* Bark of rapidly growing longleaf pine. *B.* Slower growing pine.



PLATE 4.—*A*. Branch of longleaf pine showing the terminal spring shoot with its large silvery-white winter bud. The bundles of leaves arise from the axils of the leaf bracts of the last two seasons, the first leaves of the second year having been shed. *B*. Detached bundle of mature leaves with sheath. *C* and *D*. Scales of the sheath. *E*. Transverse section through base of leaf bundle showing overlapping of sheath scales. *F*. Transverse section of an immature leaf. *G*. Section of mature leaf, showing the microscopic structure. *H*. Longitudinal section of the dorsal side of a mature leaf, showing two rows of stomata and the serrated edge (397).



PLATE 5.—A. Branch with two female aments at the end of terminal young shoot densely covered with fimbriate silvery bracts subtending leaf buds hidden in their axils; note two immature cones and a mature closed cone. B. Branch with dense cluster of male flowers surrounding apex of young shoot. C. Female ament with basal scales forming calyx-like involucre. D. Seed-bearing scales of female flowers. E. Detached male ament with basal involucre, before opening. F. Male ament, after discharge of pollen. G. Detached anthers, lower sides showing longitudinal slits of the pollen sacs just opening. H. Detached female flower, seen from above; the seed scale bears two bifid naked ovules at its base. I. Female flower viewed from below, dorsal side (397).

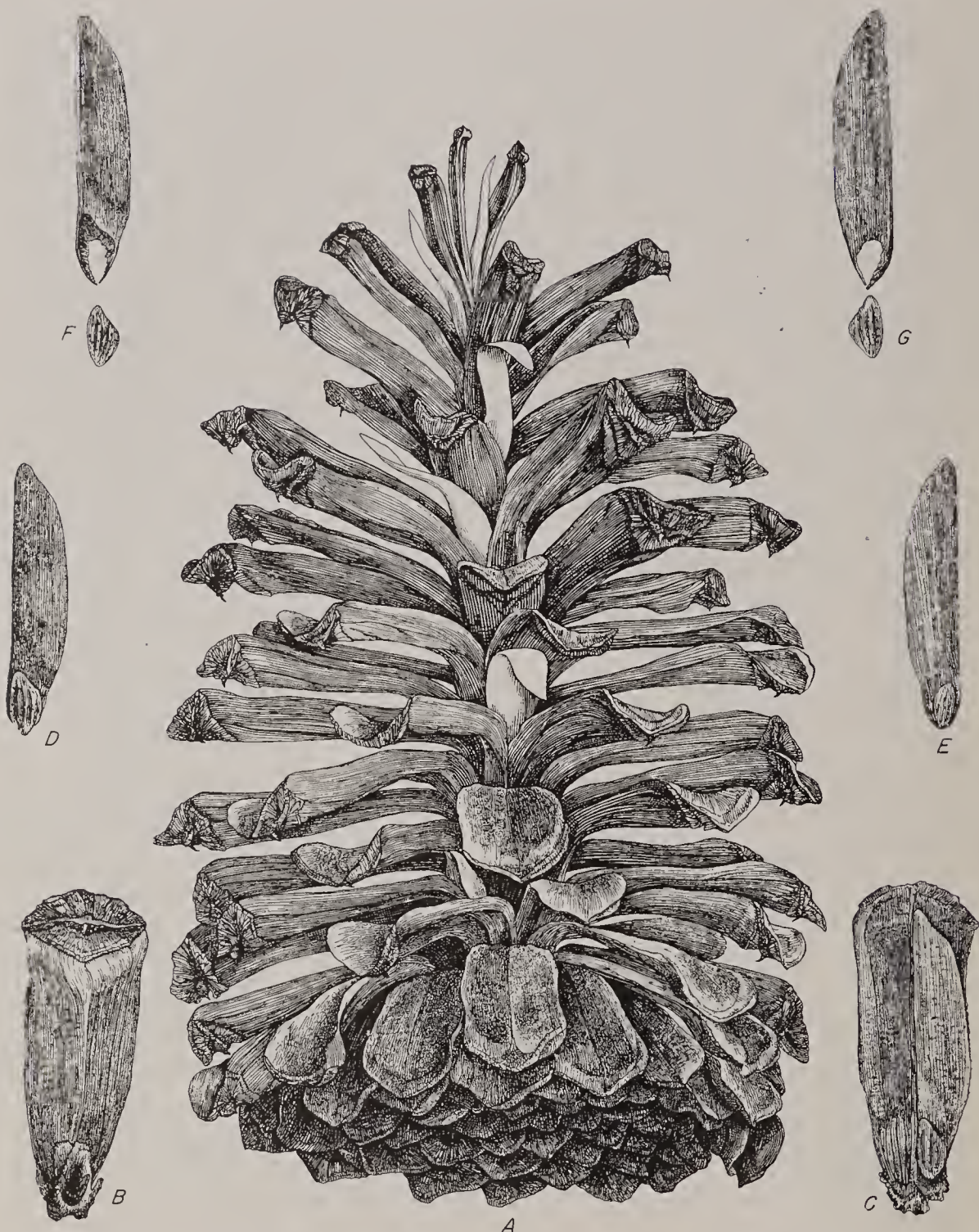


PLATE 6.—*A*. Mature open cone after shedding seed. *B*. Cone scale seen from lower or dorsal side. *C*. Cone scale seen from upper or ventral side with one seed in place. *D*. Seed, upper side. *E*. Seed detached from cone scale, lower side. *F*. Seed detached from wing, upper side. *G*. The same seen from lower side (397).

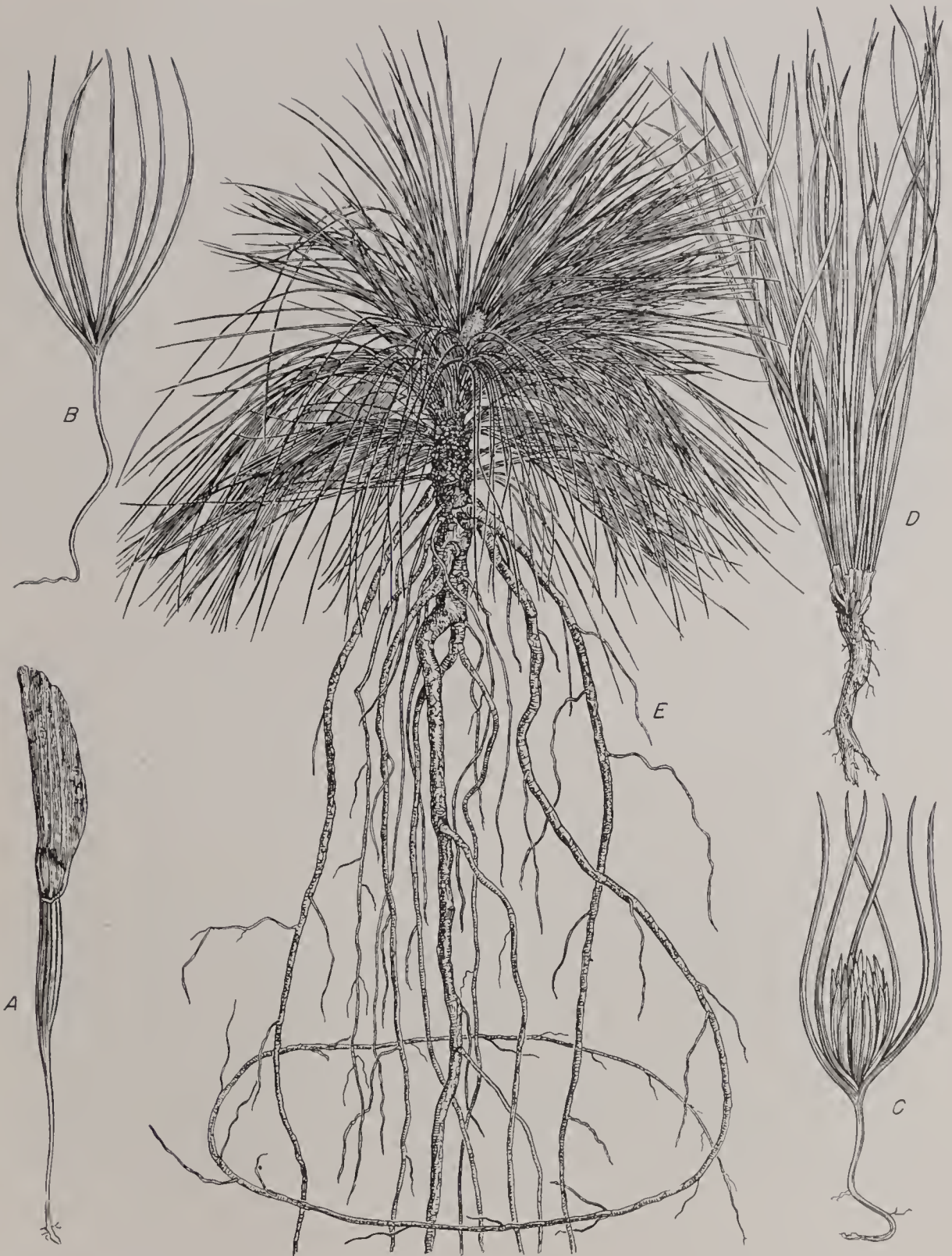


PLATE 7.—*A*. Germinating seed. *B*. Young seedling (early spring) with eight cotyledons just unfolded. *C*. Seedling a few weeks older showing central cluster of primary leaves just unfolding. *D*. Seedling at the end of the first or beginning of the second season, showing bundles of true foliage (secondary) leaves succeeding primary leaves, which have disappeared. *E*. Young tree, 3 to 4 years old, with characteristic root system (397).



PLATE 8.--*A*. Land cut clear and not yet reforested is considered the best source of virgin stumps for naval stores. Many stumps, however, are obtained from partially reproduced areas. *B*. Machine used in extracting seasoned longleaf pine stumps and taproots on flatwoods areas. This method usually yields about two-thirds more resinous wood than blasting does. F-285071, 285074

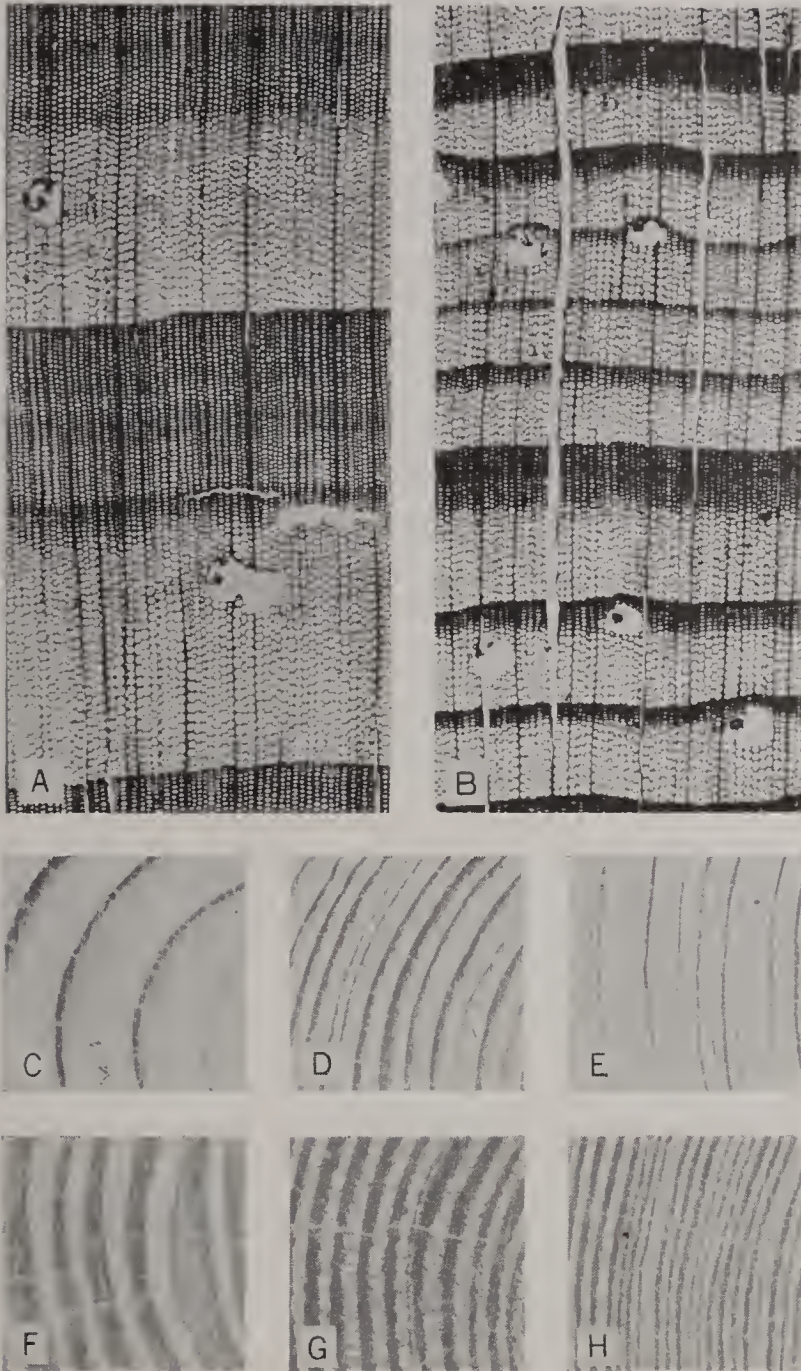


PLATE 9.—Enlarged cross sections of longleaf pine wood. *A*. Fast growing and strong. *B*. Slow growing and weak. *C*, *D* and *E*. Samples of fast, medium, and slow growth, each relatively weak because low in summerwood. *F*, *G* and *H*. Samples of fast, medium, and slow growth, each strong because of high summerwood content.

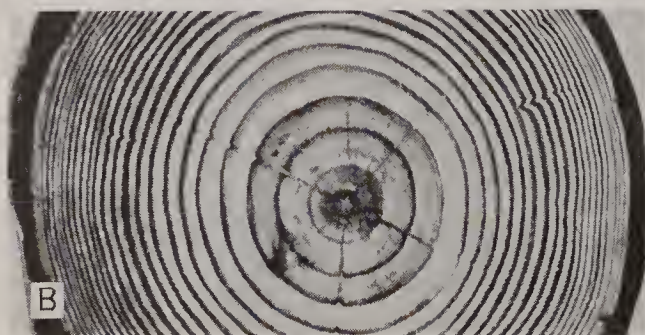
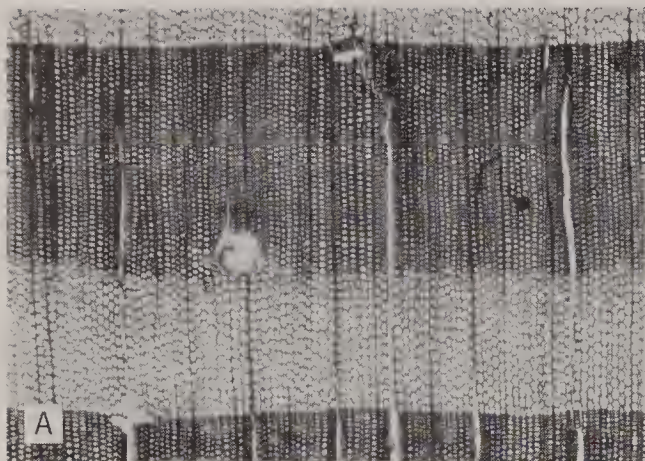


PLATE 10.—A. Thin section of wood from a second-growth stand resembling the wood from virgin timber; each narrow ring is sharply differentiated into light springwood and dense summerwood. Such wood is relatively heavy and strong. B. Section from a crowded, narrow-crowned tree showing progressive deceleration as stand grew older. C. Section from a relatively open-grown tree, with wider rings and less pronounced deceleration. D. Cross section of an annual ring. Note the gradual transition from springwood to summerwood. Such wood may shrink excessively longitudinally but is easily worked and hence is prized where high strength is not required (426). F-2734M, M-12269F, F-2733M



PLATE 11.—*A*. A hammock, unburned for 18 years, on which scattered longleaf, loblolly, and shortleaf pines remain in a thicket of dogwood and oak. *B*. This clump of turkey and bluejack oaks, succeeding longleaf, is highly resistant to upland surface fires. F-249200, 409238



PLATE 12.—On the deep sands of western Florida longleaf pine is subjected to keen competition from xeric plants, such as: *A.* Turkey oak and palmetto. *B.* The mass of roots lying just below the surface in this plant community are mainly those of grasses, gopher-apple, oak, pine, and palmetto. F-239196, 224493



PLATE 13.—Trees with thrifty and well-developed crowns like this are the best seed bearers.
F-194949

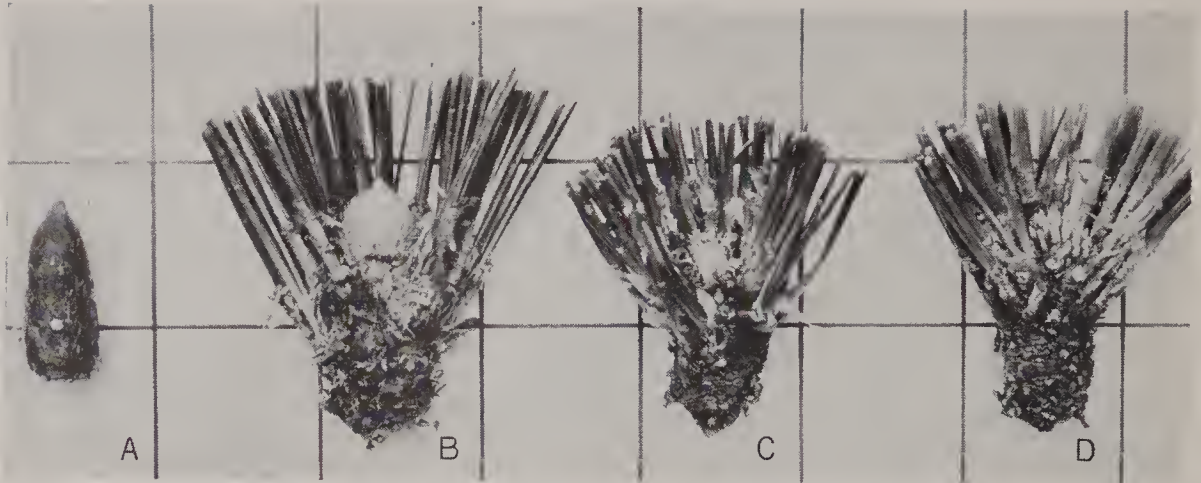


PLATE 14.—Terminal-shoot buds of longleaf pine photographed against 1-inch squares. *A.* The sharp-pointed form characteristic of thrifty seedlings. *B.* Shorter bud, sharp-pointed and vigorous. *C.* Round, loosely scaled bud, indicating an intermediate stage of vigor. *D.* Flat or "pin cushion" type of bud, which produces foliage instead of elongating the stem. *E.* Stem-forming bud in the spring, cylindrical, white, erect, thick as a man's thumb, and candlelike in appearance. F-266-340, 234971

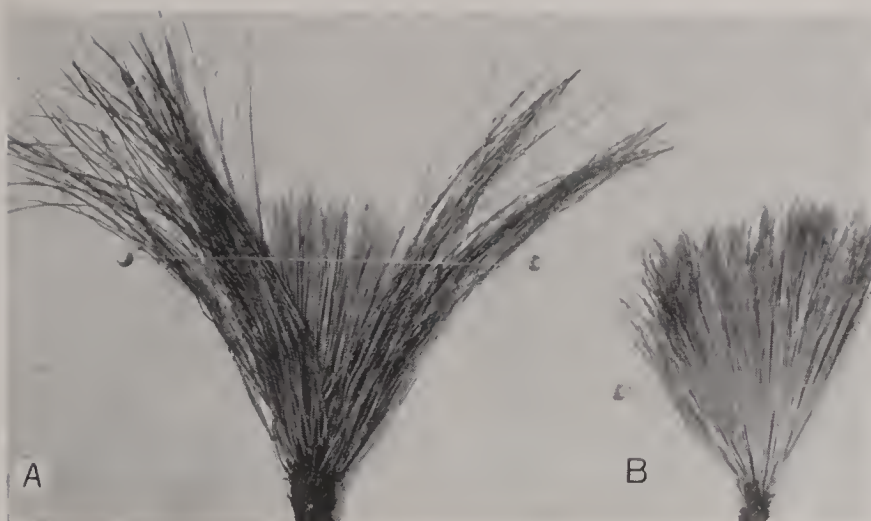


PLATE 15.—*A*. Resistant seedling which retains the long needles of the previous year. *B*. Diseased seedling which has shed all killed needles of the previous year; those of the current year are 35 percent dead. *C*, topheavy, and *D*, conical stem form of stunted seedlings. *E*. Seedling 8 inches high, but still in weakened condition (lower foliage has been removed to show juvenile and weak fascicled foliage above).





PLATE 16.—Taproots in the longleaf pine-turkey oak type of western Florida. *A*. Seedling grown in deep, dry sand. *B*. Sapling 12 years old in Norfolk sandy loam. F-259990, 255070



PLATE 17.—Despite an excellent source of longleaf seed, shortleaf and loblolly are here replacing the original longleaf on land protected from fire and subjected to unrestricted grazing by hogs. F-352135



PLATE 18.—*A*. Close association of longleaf pine with turkey oak on the deep Norfolk sands of western Florida. Longleaf pine seedlings in the grass stage near the base of a turkey oak which acts as a nurse tree. *B*. A longleaf pine tree 5 feet tall beneath an oak. Its roots draw moisture below as well as within the top foot of soil. Few seedlings so located, however, can overtop the oaks without benefit of a release cutting. F-245441



PLATE 19.—Close association of longleaf pine with turkey oak on the deep Norfolk sands of western Florida. *A*. A longleaf pine tree 5.7 inches d.b.h. working its way through the crown of an oak 10.2 inches d.b.h. The pine now suffers from crown interference (in addition to root competition) that may produce a crooked stem. Removal of the oak is obviously called for. *B*. A longleaf pine tree 7.9 inches d.b.h., 45 feet tall and 38 years old which has outdistanced an oak 8 inches d.b.h., 23 feet tall and 50 years old. Survival of the pine, accompanied by good growth and form, under such close competition is rare. F-245443-4

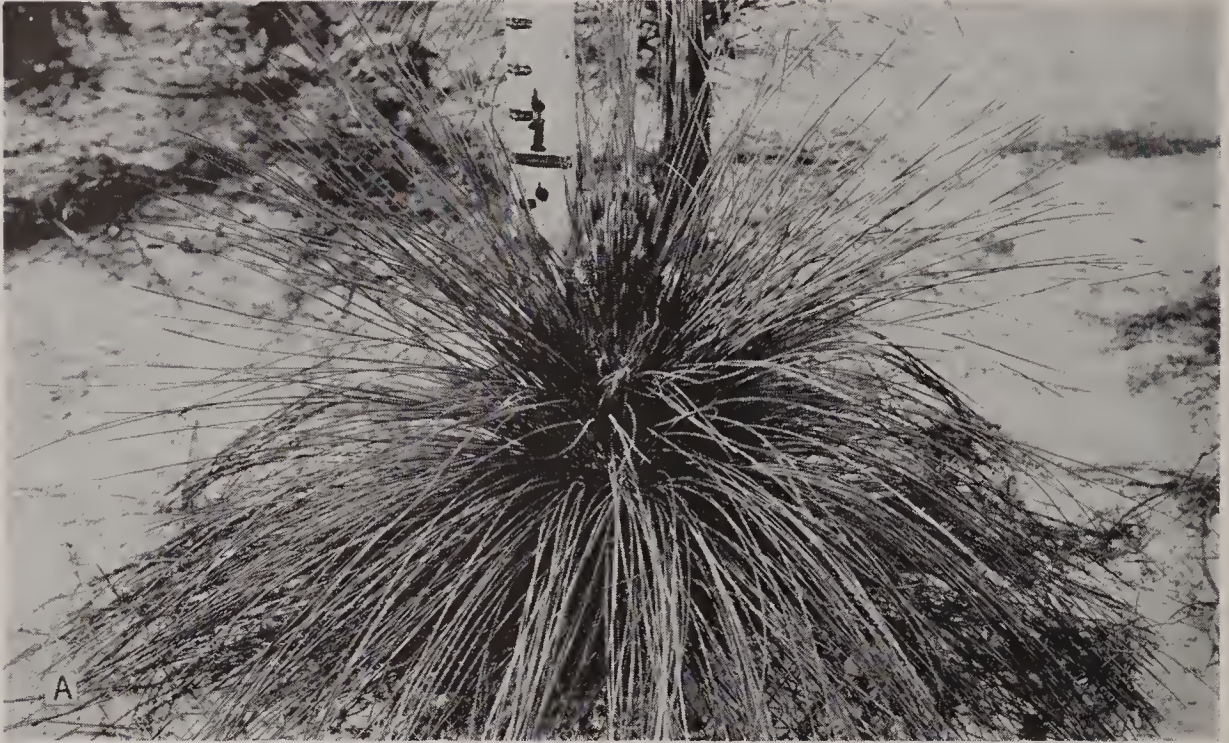


PLATE 20.—*A*. The luxuriant plume of green needles usually (but not always) offers adequate fire protection for longleaf pine seedlings. Brown-spot increases inflammability by reducing moisture content. *B*. With needles burned off back to the fascicle sheaths, the top of this seedling was killed but sprouted immediately near the ground line. F-322974, 409239



PLATE 21.—These trees remained stunted, grass-covered and infested with brown-spot disease for 12 years. When released from disease and competition at ground level, they grew 9 feet in 5 years. Adjacent seedlings that were sprayed and similarly thinned, but left in the grass, grew only about 3 feet in the same period.



PLATE 22.—*A*. Stunted longleaf seedlings behind fence and gate are here indistinguishable from grass. *B*. The same stand 18 years later. F-10511A, 244548



PLATE 23.—A. Broadleaved grass (*Andropogon scoparius* Michx.) 3 years unburned in full stands permits only partial penetration of longleaf seed to mineral soil. B. A mixture of native grasses plus a 5-year accumulation of dead grass strewn with fallen longleaf needles forms a mat that is practically impermeable to pine seeds.
F-212770, 224898



PLATE 24.—A. Needles on these two seedlings were almost completely consumed by a wild grass fire in late March. B. The same seedlings the following February, with thrifty new foliage. F-225629, 234295



PLATE 25.—A. Marked differences in height growth are shown by these 12-year-old longleaf pines in a plantation near Bogalusa, La. F-322923 B. Untreated longleaf pines 11 years old (marked by white cards) kept in the grass stage by brown-spot needle disease. Saplings in the background are also 11 years old, but were protected from the disease by frequent sprayings for 6 consecutive years after planting.





PLATE 26.—*A*. A noon fire on a windy day in a 19-year-old longleaf pine stand with a 6-year "rough" of palmetto $2\frac{1}{2}$ feet tall and gallberry 3 feet tall. *B*. Severe defoliation resulting from fire (as in this picture) may destroy dominant trees, depending on drought or other adverse conditions. F-254975, 409241



PLATE 27.—With the right kind of protection, longleaf pine forests regenerate satisfactorily. *A.* Even-aged regenerated stand on a fenced area in southern Mississippi. *B.* Development of advance reproduction at the left of the plowed furrow was greatly stimulated by the exclusion of annual grass fires; on the right, yearly burning killed all pine seedlings or left them stunted and hidden in tall grass. F-194952, 274868



PLATE 28.—*A*. After an uncontrolled fire, the pines in the background of this stand escaped death because combustible material had been removed from the forest floor by a controlled fire. *B*. A group of nearly mature trees killed by an accidental fire after about 10 years of successful fire protection. F-276-854, 225656



PLATE 29.—One of the chief benefits from controlled burning is prevention of damage from uncontrolled fire. *A.* A 19-year-old longleaf pine stand after thinning. Note prostrate stems of the unmerchantable trees cut. *B.* The same plot during a controlled fire which removed the lighter fuel from the forest floor. F-254940-1

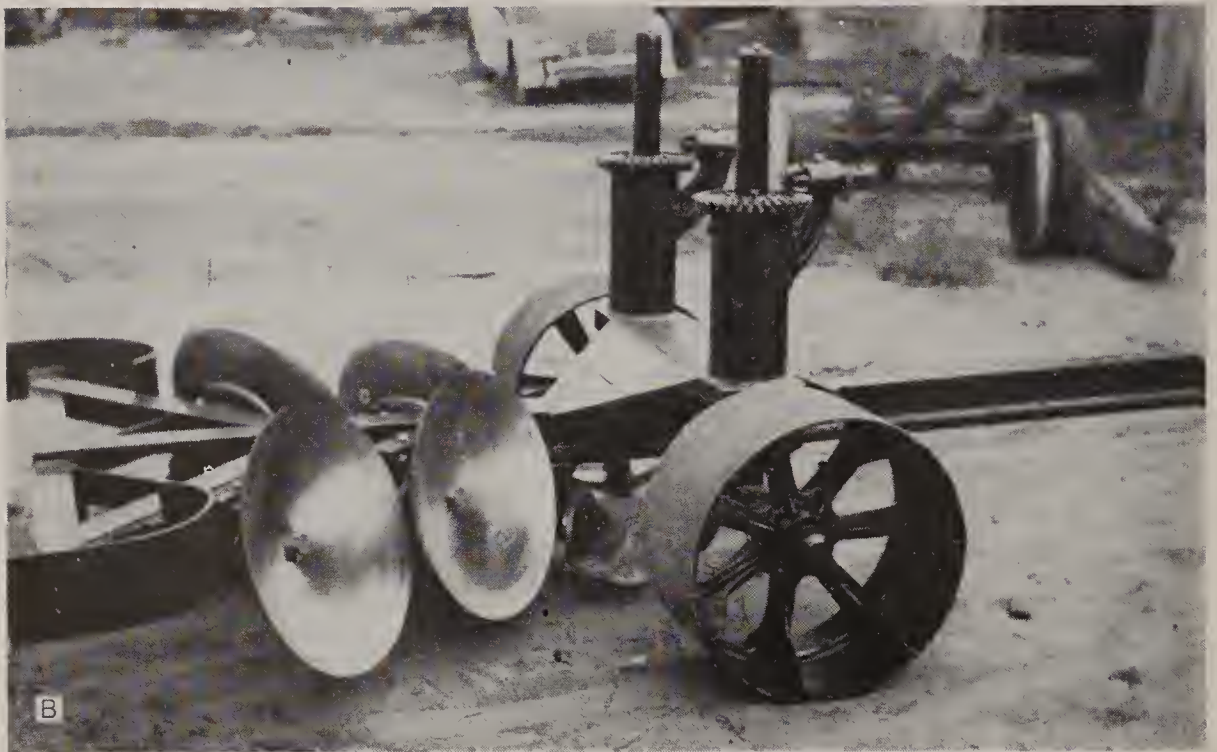


PLATE 30.—The disk plow is particularly suitable for heavy-duty presuppression and suppression work in the sandy flatwoods of the Coastal Plain. *A.* Rear view of tractor-drawn disk plow in action. *B.* Close-up of plow with disks elevated for transportation to the job. (Photographs courtesy Florida Forest and Park Service)



PLATE 31.—On small-scale timber-growing operations, fire barriers can be constructed with ordinary farm plows. *A.* Burning grass between single-plow furrows. *B.* Land restocking to longleaf pine, protected by a 30-foot burned lane between double furrows. F-256513, 254917



PLATE 32.—Because of diverse soil conditions in different localities, equipment for fire-line construction cannot be standardized. *A*. First furrow in a new fire line constructed by a single mule-drawn plow. *B*. Unburned fire line made by two trips of a tractor and 2-disk plow throwing soil to the center of a 7-foot strip. F-256376, 256530



PLATE 33.—*A.* Longleaf pine seedling deformed by repeated defoliation and injury to buds. *B.* Empty hulls of longleaf seeds found jammed wing-first into a weathered longleaf stump, the kernels eaten by rodents or birds. F-194976, 224899



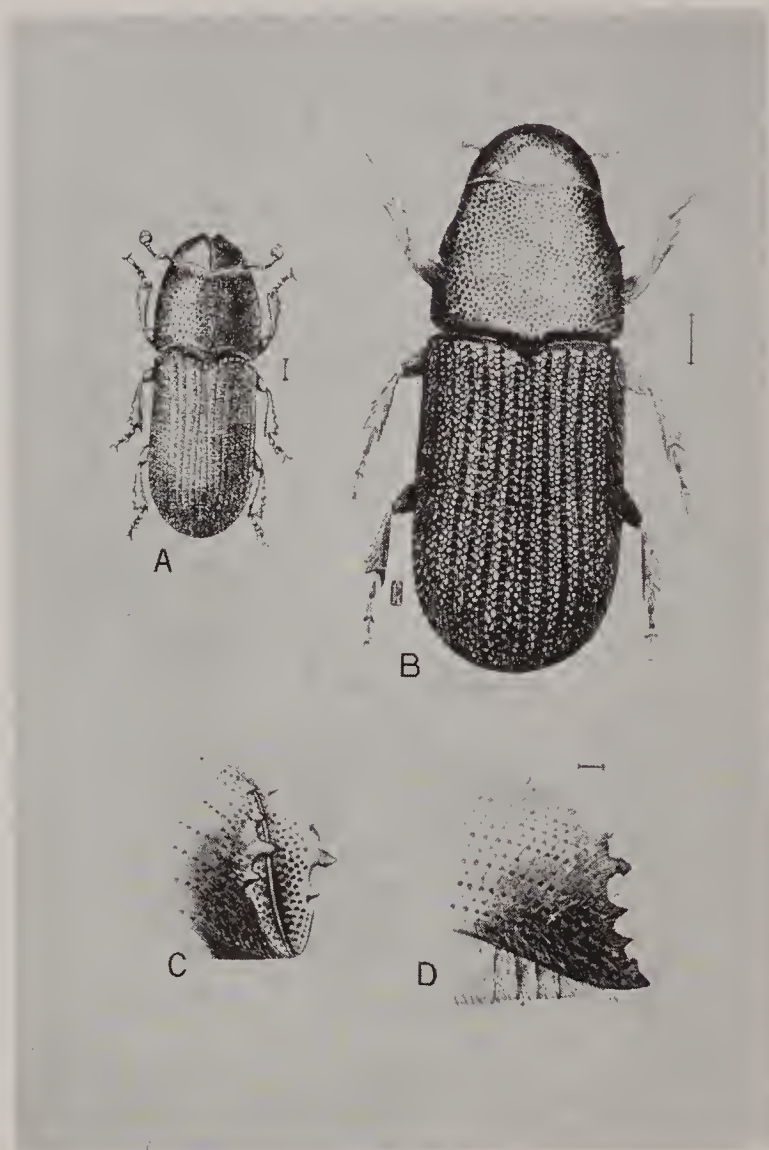


PLATE 34.—Enemies of longleaf pine. *A*. The southern pine beetle; note that abdomen has a convex shape. *B*. One of the turpentine beetles, similar in shape to *A* but larger. *C* and *D*. Posterior views of *Ips* bark beetle; the abdomen has a scooped-out appearance and is armed with toothlike projections.



PLATE 35.—Most trees die from a series of injuries, not single causes. *A*. Turpentine beetles (emergence holes marked with white paint on scorched face) have attacked this tree. *B*. Repeated fires burned their way from opposite faces to the heart, perforating the trunk. *C*. Slowly weakened by injuries and decay, trees are finally broken down by wind. F-225634, 195176, 194971



PLATE 36.—*A.* The razorback hog is the archenemy of longleaf pine, particularly on the moister sites and when other range food is scarce. *B.* Hogs break off, girdle, or uproot seedlings to get at the pungent phloem near the root collar. Such damage has often been erroneously attributed to fire. F-164852, 329665





PLATE 37.—Large isolated trees left for seed are often killed by lightning. F-2137A

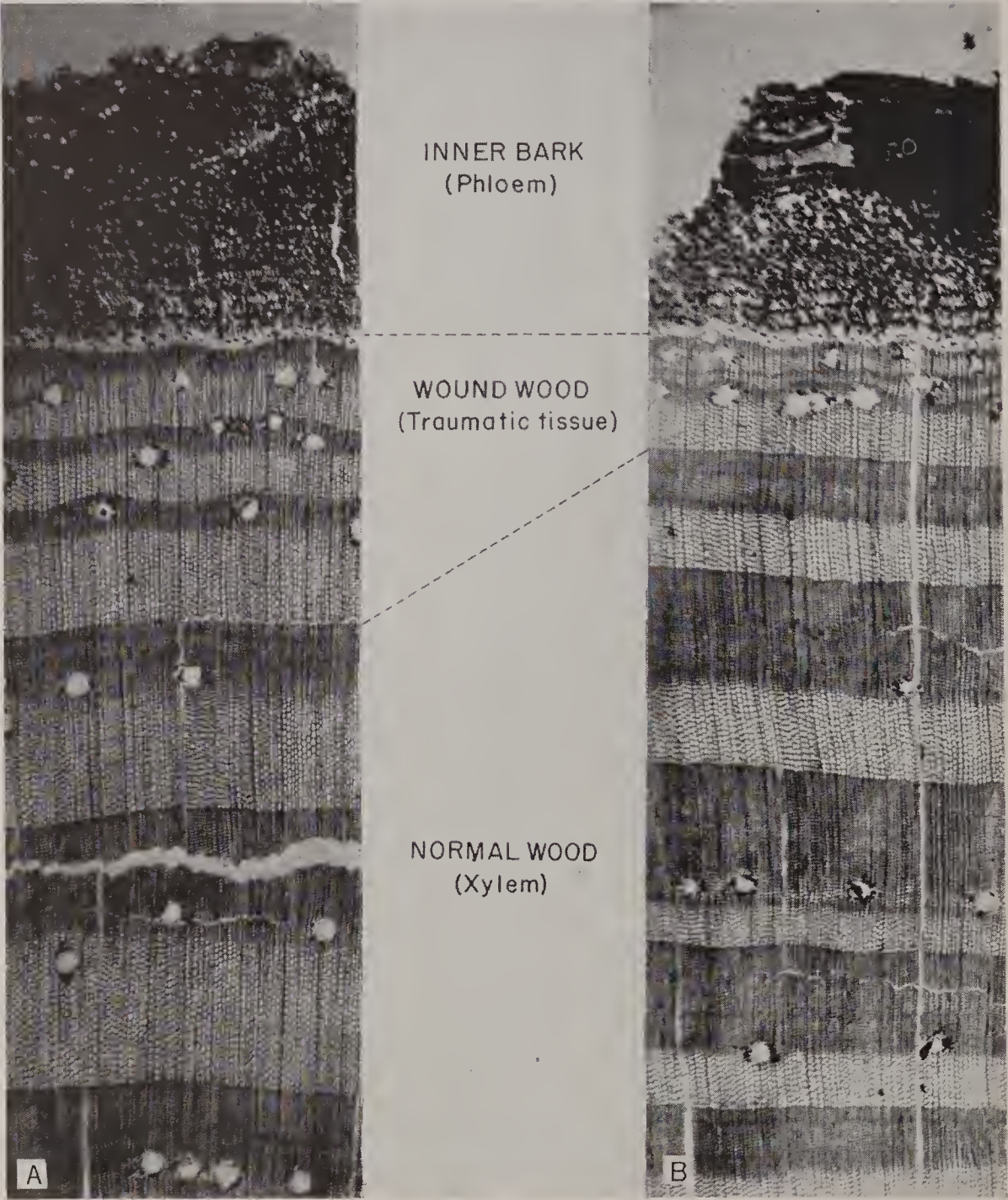


PLATE 38.—Cross section of turpentine trees. *A*. A wide-ringed tree yields almost twice as much gum as a narrow-ringed tree. *B*. Resin ducts are somewhat less numerous here than in *A*.

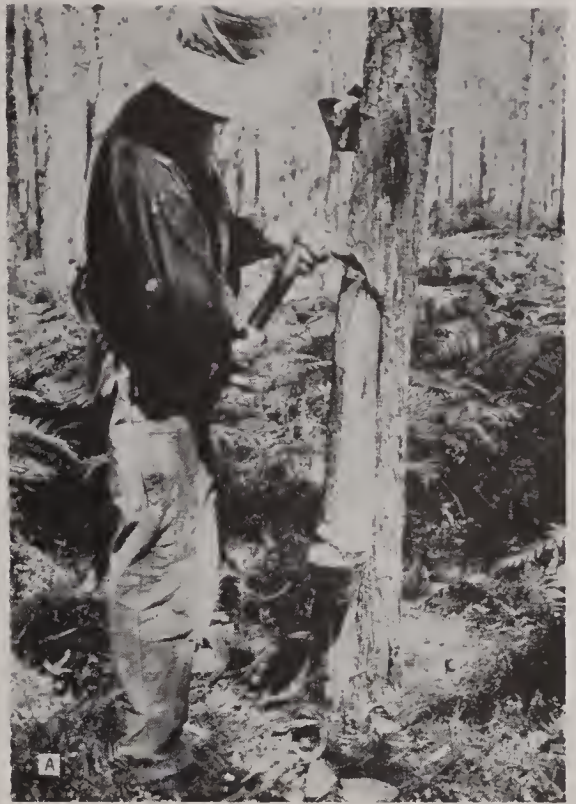


PLATE 39.—*A.* The French type of turpentine face, made with special tools, is narrower than the standard American face and hence heals over more rapidly. *B.* Twelve years of rest were required to heal the American face on this longleaf pine tree, 12 inches d.b.h. and 68 feet tall. F-208996





PLATE 40.—*A.* Exudation of oleoresin from a freshly chipped streak. *B.* "Scrape" on a turpentine face produced by the evaporation of the more volatile fractions of the gum. F-245423, 255204



PLATE 41.—A. A partly dry face. B. Turpentine face destroyed by fire. F-255179, 255183



PLATE 42.—*A.* The root of a 4-inch, 30-year-old longleaf pine, exposed by windthrow, and arrested in its downward course by a hardpan $1\frac{1}{2}$ feet below the surface of the Leon fine sand. *B.* The hardpan typical of the Leon soil exposed by wave action, Cumberland Island, Ga. F-249559, 264192





PLATE 43.—A. Mature pine tree from the longleaf pine-turkey oak type of western Florida, showing characteristic branch structure and stem. B. Shaftlike central taproot typical of mature longleaf pine, useful in anchoring the tree against the wind. F-260001, 260007



PLATE 44.—*A*. This area in Washington Parish, La., supported a virgin stand of longleaf pine, and was logged in December 1920, when the trees were loaded with an exceptionally heavy crop of ripe seeds. *B*. The same view 12 years later. Second-growth seedlings are mostly out of the grass, and the narrow crown of the central seed tree is more thrifty though not expanded noticeably. The sapling at the left bears a white mark at 4½ feet.

F-261928, 261969



PLATE 45.—Longleaf pine forests normally consist of even-aged stands, but two or more age classes are often present on adjacent areas. In *A*, second growth is absent only near the groups of remaining seed trees; in *B*, the natural reproduction is in the opening. F-196168, 256501



PLATE 46.—Long-distance hauling of longleaf pine logs and pulpwood by truck and barge is now common.
F-353499, 303463



PLATE 47.—The integrated use of a forest with a minimum of waste is facilitated by skidding tree-length logs, hauling them from the woods to a central point where they can be sectioned to best advantage, and diverting each portion to its most profitable use at the mill. (Photograph courtesy Caterpillar Tractor Co.)



PLATE 48.—*A*. The original virgin forest lands, clear cut except for patches of pole-sized timber, furnish extensive grazing areas. *B*. The less dense portions of second-growth stands are also suitable for grazing. Although the carrying capacity of the native forage is low, cattle do well in the spring on recently burned-over areas.

F-205283, 249571

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